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The effect of light, moisture and inter-species competition upon the establishment of alfalfa, ladino clover and birdsfoot trefoil

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THE EFFECT OF LIGHT, MOISTURE AND INTER-SPECIES
COMPETITION UPON THE ESTABLISHMENT OF ALFALFA,
LADINO CLOVER AND BIRDSFOOT TREFOIL

by

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INTRODUCTION

Competition between plants has been a subject of investigation for decades. Still it is one of the least understood phenomenon in the plant kingdom. Inter-species and intra-species competition is considered to be the major cause for forage stand failures. There have been many attempts to evaluate the forces of competition and to determine the growth factor or factors which become limiting when competition is present. If these factors could be qualitatively and quantitatively identified and evaluated, corrective measures might be applied to enhance establishment of forages.

This study was made in an attempt to obtain further information on the light and moisture relationships between weeds, companion crop and legume species. Soil fertility was maintained at a high level to eliminate any nutrient deficiencies which could influence these relationships. The objectives of the study were as follows:

1. To determine the effect of the companion crop upon legume establishment.

2. To determine the effect of weeds upon legume establishment.

3. To evaluate the importance of competition for light in the establishment of legumes.

4. To evaluate the importance of competition for water

in the establishment of legumes.

5. To suggest alternative methods of establishing forages which might aid in better stands being established.

The choice of legumes used in this study was based upon aggressiveness of the legumes according to Blaser, *et al*. (8). One species from each group was chosen--alfalfa from the very aggressive group, Ladino clover from the aggressive group and Empire birdsfoot trefoil from the non-aggressive group.

REVIEW OF PERTINENT LITERATURE

The literature covering the influence of competition as it relates to establishment of forages is general in nature. Most studies on the effect of light intensity and on moisture have dealt with plants in established stands and with a limited number of plants or individual clones in controlled greenhouse studies. The influence of the companion crop, with few exceptions, has been measured by altering the seeding rate, row width, variety or species of the companion crop and measuring plant survival at the end of the growing season or more commonly by hay yields taken the year following establishment. The influence of weeds has been studied from the viewpoint of yield reductions in small grains, corn or soybeans. Studies of this nature suggest the importance of competitive forces and show that factors for which competition is severe may vary from one study to another. For this reason, and to facilitate an orderly presentation, this review will be divided into four sections, namely, light intensity, water, companion crop and weeds, each as factors in stand establishment of forage seedings.

Light Intensity

One of the early references to light intensity was the work of Schantz (37). He constructed cloth shades of 5 intensities along with full sunlight over several garden crops, including lettuce, radish, potato, mustard, corn and cotton. Shades were placed over the plants at germination time and were removed after 50 days. He found that the best growth of all plants except corn occurred at intensities between one-half and one-fifth normal sunlight. With corn, however, full sunlight resulted in optimum growth. Cotton proved to be the most shade tolerant of the species observed.

Clements, et al. (12) designed an extensive series of experiments to show the importance of light, water and nutrients on plant growth. His study included sunflower, wheat, cocklebur and bluestem grown alone and in all possible two species combinations. Water was found to be the most critical of the three factors, nutrients were second and light was of importance only when stands were dense.

Böhning and Burnside (9) selected species from groups of sun and shade tolerant plants to determine the light saturation point and the compensation point for the groups as a whole. The sun plants included bean, tomato, sunflower, tobacco, soybean and cotton, each of high economic importance, and shade plants were fern, oxalis, African violet and Philodendron. In general, they found the sun species required light intensities of 2000 to 2500 foot candles as compared to light intensities of between 400 and 500 foot candles as optimum for shade plants. The compensation point for the sun species varied from 100 to 150 foot candles and for the shade species was 50 foot candles.

Forest species were investigated by Shirley (39). His work with redwood and loblolly pine showed that the light intensity needed for survival was low, on the order of 40 foot candles.

Blackman and Rutter (5, 6), studying the effect of light intensity on the growth and natural distribution of bluebell in forest sites, found that light was the main environmental factor controlling its distribution and that below an intensity of 50% daylight the rate of growth was exclusively determined by the light factor. When fertilizers were applied; nitrogen, phosphorus and potassium; the net assimilation rate was unaffected. Net assimilation rate, as defined by Black (2), is the ratio of increase in plant weight per unit of leaf area. In four instances Blackman and Rutter found that fertilizers increased the rate of growth and attributed this result to increased leaf area resulting from additional nutrients. Three of the four instances were on areas fertilized with nitrogen and the fourth was fertilized with phosphorus.

Soybeans have been investigated by many workers. Popp (34) grew plants under 6 light intensities ranging from 4285 to 26 foot candles. He found that plants under the highest light intensity were the most vigorous, had the best color and produced the largest leaves and fruit. He stated that all plants were unusually long stemmed and as light intensity decreased to 560 foot candles the plants generally grew taller. Below 560 foot candles plant height decreased. Plants grown under 26 foot candles were completely etiolated and died within 3 to 4 weeks. Hopkins (24) studied the effect of long and short days and shading on nodule development and composition of the soybean. He concluded that more nodules developed on the unshaded plants and that this was a function of carbohydrate production. Where plants were shaded, less carbohydrate was produced and fewer nodules were formed. Pritchett and Nelson (35) working with alfalfa and bromegrass found that nodulation of alfalfa decreased as light intensity decreased and was completely inhibited at 257 or less foot candles.

The response of many members of the cultivated and native grasses to light has been investigated. Benedict (1) grew crested wheatgrass, little bluestem and blue grama under screened shades adjusting the intensity from 100% to 28% of full sunlight. He found that shaded plants elongated and grew spindly and that maximum height was attained at 42% of full sunlight. Maximum dry weight was obtained at intensities greater than 70% full sunlight.

Investigations with bromegrass have been conducted by Watkins (46), Dibbern (14) and Pritchett and Nelson (35). Watkins (46) grew shaded plants at 8% full sunlight and found that dry weight at that intensity was reduced to about 1/2 of that obtained in full sunlight. Shading resulted in reducing the top growth by 35% and the underground growth by 70%. He also concluded that shading had little effect upon leaf production. Widely diverse bromegrass clones were studied by Dibbern (14) in the greenhouse under intensities of 2417, 731 and 251 foot candles for 1 year. Only those clones given more than 251 foot candles survived. He found wide differences in the degree of tolerance to shading among clones and little or no correlation between shade tolerance and their latitude of origin. His general conclusion was that while shade tolerance was of some selection value in fields of pure bromegrass, it was even more important in alfalfa-bromegrass mixtures.

Pritchett and Nelson (35) grew alfalfa and bromegrass seedlings in the greenhouse under light intensities varying from 2833 to 157 foot candles. The intensities between 757 and 157 foot candles corresponded to the intensities of light under a canopy of oats fertilized with zero to 80 pounds of nitrogen respectively. Their results showed that roots were more seriously affected than the tops by the shade treatments but both root and top dry weight decreased as the intensity of shading increased. After six weeks growth in the shade treatments, the plants were exposed to full greenhouse light. All plants made rapid recovery.

Investigations on response of ryegrass to light intensity have been conducted by Mitchell (29, 30) and by Soper (42). Mitchell (29) grew perennial ryegrass and an annual ryegrass at temperatures of 50 and 60° F. and at two light intensities, 200 and 2000 foot candles. He found that the rate of leaf appearance could be increased by either raising the temperature or increasing the light intensity. He also concluded that tiller number was determined primarily by the light energy received. In a later report (30) he stated that the net assimilation rate was determined by light intensity. He also stated that the proportion of root to plant weight was highest at the higher light intensities and lower temperatures and that the ratio could be reduced by decreasing light or increasing temperature. The same results were obtained by Soper (42). She also found that if ryegrass plants, which had been growing at full sunlight and cool (55° F.) temperatures, were subjected to lower intensities and higher temperatures, both root and shoot weights were decreased and that when they were returned to the original conditions, both root and shoot weight increased but root weight increased faster than shoot weight.

An investigation of intra-species competition among commonly grown pasture plants in Australia was conducted by Donald (15). He found that with ryegrass and prairie grass (Bromus spp.), nitrogen became the critically limiting factor as density of the plants increased. However with subterranean clover, light became critical as density increased.

Blackman (4) reported essentially the same results as found by Donald in a study of the white clover content in an Agrostis spp. sward. He concluded that loss of clover plants was brought about by shading as a direct effect and was not related to competition with the grasses. When nitrogen was applied, the loss of clover plants primarily was due to competition between species. He also stated that with infrequent defoliation, competition for light was predominant and nitrogen applications, even in small quantities may be deleterious to white clover due both to an increase in height and density of the grasses grown in association with the clover.

Mitchell (28) investigating white clover, subterranean clover and Lotus major obtained results in accord with those of Donald and Blackman. He also stated that the rate of growth of the species was reduced little by 50% shading.

Ludwig, et al. (26) studied the effect of light intensity on red clover. Observations of unclipped plants grown under intensities of 100, 30 and 12 percent daylight indicated increased stem elongation with shading and a slight increase in leaf numbers. However, after the plants were clipped to 4 inches and the same shade treatment replaced, red clover became more prostrate in growth habit and leaf number declined as light intensity was decreased. He suggested that strains of red clover could be developed for better growth with a cereal companion crop. Further information on red clover and, in addition, alfalfa and birdsfoot trefoil were reported by Gist and Mott (19). Their studies involved growing the three species under four temperatures (60, 70, 80 and 90° F.), four moisture levels and three light intensities (200, 600 and 1200 foot candles). In general, decreased top and root growth was observed when light was restricted and temperature increased. They noted a difference among legumes with red clover yields slightly greater than alfalfa at 1200 foot candles and nearly twice as large at 200 foot candles. Trefoil was the poorest producer under all treatments. Since root growth was restricted due to shading, they suggested that alfalfa, grown in shade, would be unable to obtain water from deeper depths if the plants were later subjected to drought. Where soil moisture was adequate, red clover withstood shading better than alfalfa and when water was limiting the growth of the two species was quite similar. They stated further that increasing available water at low light intensities resulted in very small responses. They concluded that irrigation of heavily shaded seedlings might actually decrease the vigor of the legumes by increasing the growth of the companion crop and that growth responses associated with increasing light are obtained only when forage seedlings are supplied with adequate water. In a later study

(18) they subjected the same three species to two light intensities, 200 and 1200 foot candles for varying time lengths. Again trefoil gave the poorest response and red clover proved to be more shade tolerant.

Bula, et al. (11) reported on light intensity changes under 5 varieties of oats seeded at 2 bushels per acre and Clinton oats seeded at six rates (1/2 to 3 bushels per acre). Results from their study indicated that seeding rate influenced light intensity only prior to full heading or ripening. After this period the light intensity was virtually the same under all rates. At the lighter rates, weed ingress aided in restricting light intensity at legume height. Counts of alfalfa and red clover populations were not significantly different among any of the varieties or among the seeding rates.

Black (2), summarizing the effect of light intensity on herbage plants, stated that alfalfa, white clover, alsike clover and red clover are sun species and that any reduction in light brings about a reduction in growth rate. He stated further that grasses, like legumes, make their best growth at or near full sunlight.

More recently, Rhykerd (36) investigated the influence of light intensity, quantity and duration on the growth of alfalfa, red clover and birdsfoot trefoil seedlings under light intensities of 100 to 3200 foot candles for varying time lengths during each 24-hour growth period for 15, 30 and 45 days. He concluded that a 12-hour illumination period at a constant light intensity was more efficient in dry weight production than variable intensities during the light period which result in the same total energy. He found that only at a light quantity less than 4800 foot candle hours per day was a higher intensity for a shorter period of time as efficient as a long illumination period at a lower intensity. Comparison of the legumes tested showed birdsfoot trefoil to be inferior to the other legumes as measured by top and root growth.

In summary of this section of literature review, reduction of light intensity, whether caused by artificial shading or vertical competition among species growing together, restricts both top and root growth but in a disproportionate amount. Root growth usually is more restricted than top growth. It follows that resistance to drought may be reduced and subdominant species in association may be severely restricted by the associated species. Adequate moisture at reduced light intensity has little influence upon the growth of the plant but if a tall and short growing species are grown together, may prove to be deleterious to the short growing species. The light intensity required for survival is quite low. Maximum intensity for best production seems to be approximately 40 to 50 percent of full sunlight for legumes while with grasses maximum dry weight is obtained at intensities near full sunlight.

Irrigation

The importance of water in all life processes is axiomatic. Perhaps, for this reason, most investigators of plant competition have credited water with being the growth factor for which competition is most severe. Clements (12) attempted to evaluate the importance of water by measuring leaf area and plant weight of sunflower, wheat, cocklebur and bluestem by growing them in pots containing soil of various moisture contents. He found that when moisture was deficient the values obtained were lower than when nutrients were deficient or when water was adequate and light was deficient. With underplanted species he found the values were lowest when water was deficient.

A study by Nelson and Robins (31) of irrigated Ladino clover-orchardgrass pastures showed that the frequency of irrigation was very important. In this study yields were higher when fields were irrigated every 7 to 11 days than when irrigation was applied every 15 to 20 or 20 to 30 days. In addition to higher yields, the most frequently irrigated treatments produced the highest per cent of clover in the mixture.

Houston (25) in a study with irrigated alfalfa found that supplementary water resulted in a complementary relationship between grasses and legumes in that the yield of forage per unit of water was greater when alfalfa and grasses were grown together than when alfalfa was grown alone.

Perhaps the most conclusive study of water relations in pasture species was conducted by Gösta (21). Stands of pure alfalfa, alfalfa plus grasses, white clover alone, white clover plus grasses and reed canarygrass were used. He found that when a shortage of soil moisture existed a positive correlation was evident between growth rate and water supply. Temperature and light, under these conditions, had little or no influence. Partial regression coefficients showed both water and light to be beneficial and temperature to be detrimental. When pastures were exposed to a surplus of water, both light and temperature were important as shown by strong positive partial coefficients. He concluded that where water is sufficient light may easily become the limiting factor.

In summary of this section, the importance of moisture cannot be underestimated. However, little information is evident in the literature concerning moisture competition of associated species. It has been shown that under unfavorable moisture conditions, growth response is conditioned by available water. Under low light intensities, water ceases to be as important as under high light intensities.

Companion Crop

The desirable characteristics of a small grain companion crop have been suggested by Flanagan and Washko (17). They observed six varieties of oats and one of barley used as companion species in the establishment of alfalfa, birdsfoot trefoil, Ladino clover and red clover. They concluded that a small grain should be short, have few stems, stiff strawed and permit good light infiltration. As an integral part of their study they measured reflected light from a white surface at ground level. They concluded that while light intensity was not directly a causative factor in legume stand losses, it provided an indication of the competitive effect between the various small grain varieties and the legume seedlings. This conclusion was based upon the fact that with higher light intensities, due to fewer small grain stems and shorter plants, larger red clover stands and smaller losses in alfalfa and red clover plants were found. Through multiple correlation analysis, a significant correlation was found between reflected light reading and the three factors: number of stems, grain height and grain plus straw yields. Higher light readings were obtained under barley than under oats. In summary, they found that there may be great differences between varieties of a crop as well as between crops.

Collister and Kramer (13) studied the effect of oat variety on the stand and development of red clover. They found, using 7 selected varieties, that varieties may cause measurable differences in the stand and development of red clover. Their results are somewhat different from those of Flanagan and Washko (17) in that a nonsignificant correlation was found between oat yield and red clover stand.

The influence of the rate of sowing the companion crop upon legume establishment was reported by Smith, et al. (40). They grew alfalfa and red clover, in mixture, under 6 seeding rates from 1/2 to 3 bushels per acre, with four varieties of oats. The study was conducted on heavy soil over a four-year period and on light sandy soil for a three-year period. Their criteria of measurement was the number of legume plants established each fall. They found that on the heavy soils stands were not greatly reduced as the rate of seeding of the companion crop was increased. This was due in part to weed ingress in the lighter seeding rates. On the thin sandy soils poor stands occurred under the heavy seeding rates. They attributed this to competition for moisture.

Row spacing of small grains has been investigated by Harper (22), Dungan, et al. (16), Pendleton and Dungan (33) and others. All studies reported are in agreement that in years of normal or above normal rainfall row spacing has little effect upon legume stands but during dry season better stands are obtained with wider row widths.

Thatcher, et al. (44) stated that in wet seasons the companion crop creates severe competition through shading and lodging of the small grain and that in a dry season competition for water becomes severe. They suggested sowing forages alone to avoid entirely the competition of the companion crop. The same suggestion was made by Vann (45) in the establishment of birdsfoot trefoil.

McClelland (27) studied the effects of various fertilizers on growth and development of oats and reported that the fertilized oats tiller earlier, have more rapid growth and shade the ground earlier than unfertilized oats. The suggestion was made that oats, well fertilized with nitrogen or phosphorus, may create severe competition between the small grain and the undersown forage seedlings.

A study on the effect of the companion crop on the establishment of orchardgrass and ryegrass in Scotland was reported by Heddle and Herriott (23). They grew both forage species alone and under a barley companion crop and found that the cereal crop depressed tillering and plant establishment of both forages during the seeding year. The conclusion was reached that the cereal crop was beneficial to plants which establish more slowly through their effect on weed control. This conclusion was based on the findings that fewer plants of orchardgrass were established without a barley companion crop than with the species present. The competitive effect of weeds was greater than the competitive effect of barley.

Another study showing the effect of weed control through a companion species was reported by Stahler (43). He used competing crops of rye, wheat, alfalfa, soybeans, millet, Sudangrass, sunflower and hemp to control field bindweed. Where soil moisture was inadequate, bindweed stands were maintained quite successfully with practically all crops. However when moisture was adequate, light became the controlling factor and it was found that bindweed could be controlled through wise selection of companion species together with timely seeding of the crop. Fall seeded rye or wheat, alfalfa and summer seeded crops of millet, sorghum, soybeans and Sudangrass demonstrated their ability to restrict light penetration. Sunflower and hemp lacked the uniformity and rapidity of growth to meet the requirement of canopy dominance and light restriction.

A general concept of the influence of the companion crop upon legume establishment was given by Westover (47). He stated that the chief objections to a nurse crop are that it draws heavily on soil moisture supply and that it is harvested at a time during the year when the sudden change from shade to bright light is injurious to legumes. He also stated that the small grains probably are no more competitive to legumes than the heavy weed growth which generally results from early seedings without a companion crop.

In general, previous studies show the influence of the companion species can be both beneficial and detrimental. It is beneficial for weed control during the early phase of forage establishment, but it is detrimental in that it may seriously limit light and moisture. The suggestion has been made that legumes can be established without a companion crop. However, weeds may cause as much or more competition than a companion crop.

Weeds

Studies relating to the influence of weeds upon legume establishment are relatively few in number. Some indication of the influence of weeds has been inherent in other studies. Bula, et al. (11) showed that forages established under light seeding rates of the companion crop were no better than forages established under heavier seeding rates of the companion crop because of the weed ingress into the lighter stands. Smith, et al. (40) stated that on heavy soils, prominent weed growth in thinly sown oats resulted in legume stands comparable to that under heavily seeded oats. Heddle and Herriott (23) found that the effect of weeds on the establishment of orchardgrass was as great as the effect of the barley companion species.

A more exact effect of weeds on stand establishment of trefoil was determined by Brunk (10). This study, made during a normal and an abnormal year with respect to rainfall, showed weeds decreased birdsfoot trefoil yields during establishment by 95% in the dry season and 83% during a normal rainfall season. Plant counts, measured as the number of plants per square foot, were decreased by 12% during the dry season and 20% during the normal year due to the influence of weeds. Weight per plant was decreased by 85% during both seasons.

Since small grains are most commonly used as companion crops in forage species establishment, the extent of competition between weeds and small grain is worthy of note. Blackman and Templeman (7) hand seeded common weeds in oats and barley seedings to determine the nature of competition between the small grain and annual weeds. They concluded that the intensity of competition depended upon the species of weed present and that the critical period seemed to be in the early stages of growth of the cereal. During years of normal rainfall, light and nitrogen become limiting and especially light when the weed species is tall growing and of high density. They suggested that where nitrogen was the limiting factor, it might be more economical to increase the yield of the companion crop by nitrogen fertilization rather than by weed suppression.

Godel (20) suggested using heavier seedings of small grain and fertilizing, particularly with phosphorus, to overcome weed competition. It was his opinion that more small grain plants could be established thereby limiting the opportunity for weed development. McClelland (27) suggested the same treatment because of the early tillering and growth and quick shading effect of the companion crop resulting from phosphorus applications.

Studies on root development by Pavlychenko and Harrington (32) led to the conclusion that moisture was the most important consideration in weed versus crop competition. They found that inadequate water supply was manifested in decreased top growth and that light became important only after plants shade each other.

In another study, Blackman (3) concluded that competition for water was most severe and that competition for light was important only during years of normal or above normal rainfall. He stated further that in dry years the cereal crop may "grow away" from weeds. Nutrient availability was of little consequence in weed-small grain competition.

With regard to the effects of weeds, it appears that soil moisture relationships determine the degree of competition between forages and weeds. In dry years, weeds become important because they compete for soil moisture. Wet years favor the growth of weeds and vertical competition for light becomes the controlling factor.

MATERIALS AND METHODS

Field Study

The site used for these investigations was a level area on the Atomic Energy Commission farm at Ames. The soil was classified as Colo Silt Loam[1]. Field measurements and borings made to a depth of forty inches indicated near neutral pH, virtually no color change and uniformity of texture.

The experimental site for the 1956 planting had been in corn in 1955 and was spring plowed in 1956. At the time of plowing, the field was fertilized with 0-48-0 at a rate of 200 pounds per acre. The land was tandem disked and smoothed with a spike-tooth harrow prior to seeding.

The seeding operation was accomplished with a tractor mounted, power take-off driven grain drill adapted to simultaneous seeding of small grain and forage seed and fertilizer application. The forage seed were placed over, but not in contact with, a band of fertilizer, i.e. "band" seeded. The seeding was made on April 10 using Clintland oats seeded at 1.7 bushels per acre and Ranger alfalfa, Ladino clover and Empire birdsfoot trefoil seeded at 10, 2 and 6 pounds per acre respectively. Certified seed of high germination and

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[1]Rieken, Frank F., Ames, Iowa. Soil classification. Private communication. 1959.

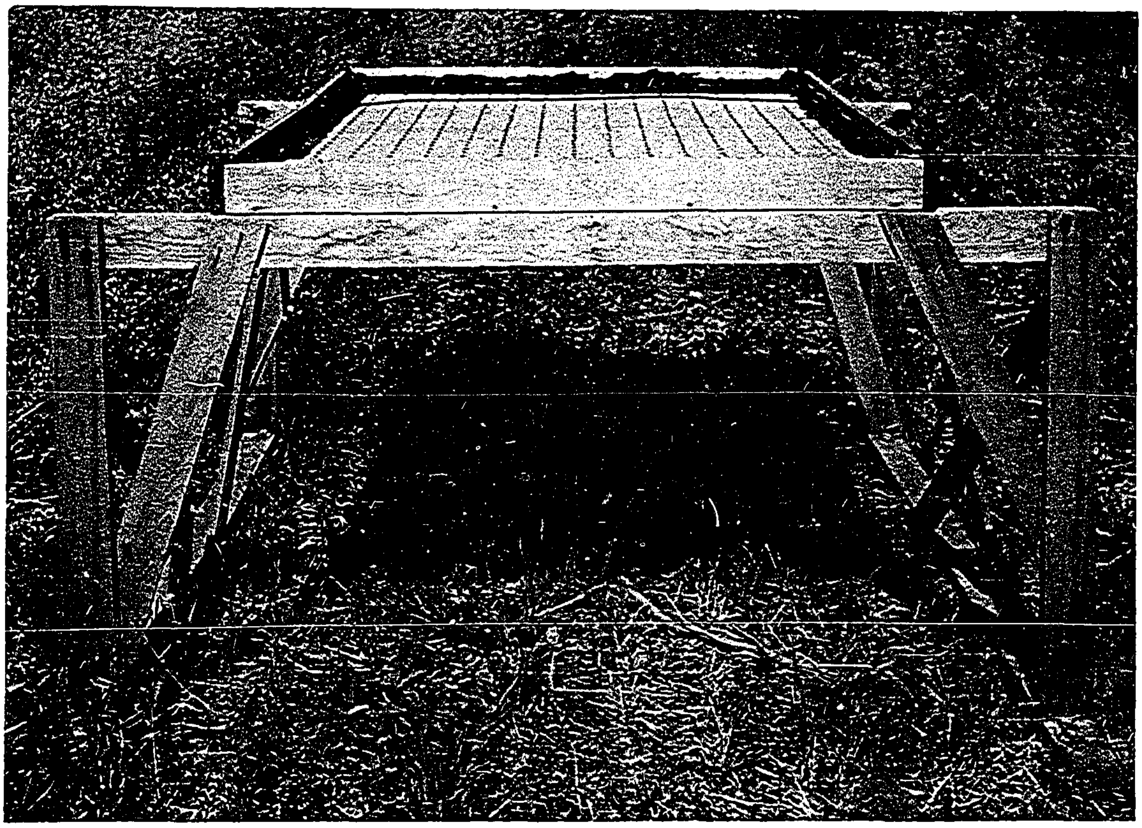
purity were inoculated in the recommended manner on the day of seeding. A complete fertilizer, 4-16-8, was applied to all plots at the rate of 250 pounds per acre at the time of seeding.

The seeding in 1957 was made on April 12 on an area that had been in alfalfa in 1955 and 1956. Two changes were made in the 1957 plantings: a) Cherokee oats were used instead of Clintland oats and b) the field was cultipacked immediately following seeding as contrasted to no cultipacking in 1956. All other practices were the same as in 1956.

A split plot design was used in this study with randomization of the three legumes, alfalfa, Ladino clover and birdsfoot trefoil, as the whole plots. The sub-plots consisted of eight randomized treatment combinations including: a) two levels of the companion crop, none and 1.7 bushels per acre; b) two levels of weeds, natural weed infestation and weeds removed; and c) two levels of irrigation, irrigated and not irrigated. The individual plot size was 6 feet by 10 feet. Four replications were used. The area sampled for subsequent measurements was the center three feet of the center three rows of each plot.

Supplementary water in the irrigation treatments was applied by means of specially built water tables (Figure 1) which permitted slow application of water. The frequency of irrigation was determined by soil moisture determinations

Figure 1. Plot size irrigation table used for controlled application of water



taken at 6-inch intervals to a depth of 24 inches. Field capacity and wilting point for the experimental site were determined prior to initiation of irrigation treatments in 1956. Table 1 summarizes these findings.

Table 1. Soil moisture determinations of Colo Silt Loam on the Atomic Energy Commission Farm at Ames Iowa in 1956

Depth (inches)	Field capacity (%)	Wilting point (%)
6	26.3	12.3
12	25.8	15.2
18	29.9	16.0
24	26.2	14.9

Water levels on the irrigated plots were maintained near 60% field capacity during the period of the investigation. The irrigation dates and amount of water applied at each date are shown in Table 2. The May 4 application in 1957 was necessitated by the dry fall season in 1956 and below normal rainfall prior to May 1 in 1957.

Weed control, on those plots where weed removal was indicated, was started soon after the emergence of the small grain companion crop and was continuous throughout the season.

The first harvest was made July 16 and July 17 of 1956 and 1957 respectively. At this time all plots were cut, the sample areas harvested separately, bagged and taken to a cold

Table 2. Irrigation dates and amount of water applied during the 1956-1957 growing seasons

Month	1956		1957	
	Day	Amount (inches)	Day	Amount (inches)
May			4	2.37
June	21	1.00		
	29	1.25		
July	6	1.25	2	1.25
	13	1.25	10	1.25
	20	1.25		
	27	1.00		
August	3	1.00	7	2.00
Total		8.00		6.87

room until they could be hand separated into the components of material present. A second harvest was completed in the first week in September of both seeding years and the material was handled as in the previous harvest. As soon as possible after harvest, the material was hand separated into the general classifications of legumes, weeds, grain and straw plus chaff. The separated material was then dried to a constant weight and recorded. The 1957 plantings were sampled twice in 1958.

Chemical control of leafhopper was imposed on all treatments during all years.

Some damage to plots occurred during the entire period the studies were underway due to cattle escaping from an adjacent field. In addition to this, the 1957 plantings were subjected, late in the season, to unnecessary damage due to vehicles and farm implements being driven over the experimental site.

During the year of establishment, measurements taken included weight of legumes, weight of weeds, weight of straw and chaff, weight of grain, weight per 1000 kernels and number of legume plants established at the end of the season. Measurements of the 1957 plantings taken in 1958 included legume yield, weed yield and plant counts.

Weather data taken at the Agronomy Farm weather station three miles away indicated that 1956 was characterized by temperatures slightly below normal in April and July and above normal in May, June and August. June was the warmest month with temperatures averaging 4.7 degrees above normal. Only during August was rainfall above normal. The period from April 1 to September 1 was deficient in moisture to the extent of 5.25 inches. Eight inches of supplementary water was applied between June 21 and August 3. In 1957, April and August temperatures were normal, May and June were slightly below normal and July was 2.4 degrees above normal. Moisture conditions in 1957 were much more favorable in that only during August was rainfall deficient. During the period July 2 to August 7, 4.87 inches of supplementary water was applied. The 1958 season was characterized by temperatures above normal in April and May and considerably below normal in June and July. Climatic data are summarized in Table 3.

Table 3. Mean monthly temperatures and total monthly rainfall at the Ames Agronomy Farm weather station during the period April 1 to September 1 for the years 1956-1958[a]

Month	1956		1957		1958	
	Average monthly	Departure from normal	Average monthly	Departure from normal	Average monthly	Departure from normal
			Temperature (°F.)			
April	47.1	-1.9	49.7	+0.6	49.2	+0.1
May	62.2	+1.6	58.6	-1.8	62.4	+2.0
June	74.7	+4.7	68.8	-1.5	65.8	-4.5
July	73.7	-1.2	77.6	+2.4	69.8	-5.4
August	73.3	+0.9	72.6	+0.1	72.2	-0.3
			Rainfall (inches)			
April	1.63	-0.93	2.87	+0.34	1.63	-0.90
May	3.95	-0.23	6.19	+2.16	1.66	-2.37
June	1.56	-2.78	6.50	+0.99	4.29	-1.22
July	1.61	-1.81	3.48	+0.29	9.59	+6.40
August	4.25	+0.55	3.41	-0.51	1.78	-2.13

[a]Taken from the U. S. Weather Bureau Summary.

Shaw and Duncan (38) indicated subsoil moisture in November of 1955 and 1956 at the Agronomy Farm to be near 20% field capacity. In 1957 subsoil moisture was well above 50% field capacity. These climatic factors are important in explaining the experimental results.

Greenhouse Study

To gain further information about the effect of shading and irrigation on young seedlings of the three legumes tested in the field, a study was established in the greenhouse to measure these effects. The greenhouse was without benches and permitted direct seeding into the soil _in situ_. The area was pre-irrigated, spaded and raked smooth prior to seeding. A complete fertilizer, 4-16-8, was applied at a rate of 450 pounds per acre prior to raking and smoothing.

Certified seed of Ranger alfalfa, Ladino clover and Empire birdsfoot trefoil of high germination and purity were properly inoculated and seeded with a V-belt seeder on September 23, 1958. Each plot consisted of 3 rows, 10 feet long and one foot apart, of each legume. The seeding was lightly sprinkled each day for a period of two weeks to insure good germination. Daytime temperatures were near 80° F. and nighttime temperatures were near 65° F.

At the end of two weeks, the plants were thinned to 1 plant per inch of row and weeds were removed from between the rows. Metal shades, 8 feet square and 3 feet high, were set up at that time over the seeded areas. The shades were constructed of 1 by 2 inch framing with metal strips covering 50, 75 and 90 percent of the framed area. Dams were constructed within each of the shade treatments which permitted irrigation of one-half of each treatment. One series of plants were left unshaded to serve as a check. Metal dams also were placed in this area to permit irrigation of one-half of the seeded area. Five irrigations, one week apart, were applied to the areas designated to be irrigated. Between three-fourths and one inch of water was applied at each irrigation. Because of space limitations and size of the metal shades, this phase of the study was not replicated. A population size of 30 plants of each legume was randomly chosen, where possible, for the harvest sample.

Seven weeks after seeding the shades were removed, plant samples taken and measurements recorded. The plants were dug up with a small trowel and top and root length, leaf number and nodule number were recorded. Both top and root samples were then dried to a constant weight and weighed on an analytical balance.

EXPERIMENTAL RESULTS

The results of these investigations will be presented in two sections, namely, field and greenhouse studies. Each criteria of measurement used in the field investigation is presented and summarized. Greenhouse results are summarized on the basis of treatment effects.

Field Study

Plant population

The plant population was determined at the end of the seeding year, 1956 and 1957, and in 1958 for the 1957 seeding at the end of the first harvest year. With Ladino clover, grown in the absence of any competition during establishment, it was impossible to determine the number of plants present because of the heavy stolon growth. The same situation prevailed at the end of the first harvest year of the 1957 seedings. In these instances, visual estimation of ground cover were obtained and expressed as a percentage of the area covered.

The data in Table 4 give the plant populations for the year of seeding expressed as the total number of plants for legumes and treatment combinations summed over the four replications. The results obtained are shown also in Table 5 and Figures 2, 3 and 4 as the number of plants established per

Table 4. Plant population of alfalfa, Ladino clover and birdsfoot trefoil established with and without a companion crop, with and without weeds and with and without irrigation, measured at the end of the seeding year and of the 1957 seedings measured in the fall of 1958[a]

Treatment Combinations								
Companion crop	+	+	+	+	-	-	-	-
Weeds	+	+	-	-	+	+	-	-
Irrigation	+	-	+	-	+	-	+	-
				1956				
Alfalfa	127	181	75	160	225	260	259	239
Ladino clover	0	0	1	0	0	2	99[b]	78[b]
Birdsfoot trefoil	0	0	12	0	2	13	29	33
				1957				
Alfalfa	4	15	32	19	19	57	360	442
Ladino clover	17	7	20	3	13	1	100[b]	100[b]
Birdsfoot trefoil	0	0	1	0	2	0	114	122
				1958				
Alfalfa	8	11	25	8	17	29	89	101
Ladino clover[b]	91	41	92	50	66	49	99	82
Birdsfoot trefoil	20	24	28	28	32	52	48	44

[a]Values shown are the sum of plants present in four replications.

[b]Values shown are an average visual estimation of ground cover, in per cent.

square foot for each treatment.

In general, fewer plants were established in 1957 than in 1956. This can be attributed to more abundant weed and companion crop growth in 1957 when rainfall was above normal. Weed height in the absence of the companion crop was nearly

Table 5. Average number of alfalfa, birdsfoot trefoil and Ladino clover plants per square foot under eight treatment combinations of companion crop, weeds and irrigation measured at the end of the seeding year and of the 1957 seeding measured at the end of the first harvest year.

Treatment Combinations								
Companion crop	+	+	+	+	-	-	-	-
Weeds	+	+	-	-	+	+	-	-
Irrigation	+	-	+	-	+	-	+	-
				1956				
Alfalfa	6.0	8.6	3.6	7.6	10.7	12.4	12.3	11.4
Ladino clover	0.0	0.0	0.0	0.0	0.0	0.1	99[a]	78[a]
Birdsfoot trefoil	0.0	0.0	0.6	0.0	0.1	0.6	1.4	1.6
				1957				
Alfalfa	0.2	0.7	1.5	0.9	0.9	2.7	17.1	21.0
Ladino clover	0.8	0.3	1.0	0.1	0.6	0.0	100.0[a]	100.0[a]
Birdsfoot trefoil	0.0	0.0	0.0	0.0	0.1	0.0	5.4	5.8
				1958				
Alfalfa	0.4	0.5	1.2	0.4	0.8	1.4	4.2	4.8
Ladino clover[a]	91.0	41.0	92.0	50.0	66.0	49.0	99.0	82.0
Birdsfoot trefoil	1.0	1.1	1.3	1.3	1.5	2.5	2.3	2.1

[a]Values shown are visual estimates in per cent ground cover.

seven feet at grain harvest time on the irrigated plots. Figure 5 shows weed growth at that time.

Because so few plants were established in 1956 with Ladino clover and birdsfoot trefoil, the data for each of the legumes were analyzed separately for both seasons. The analysis, with selected comparisons, of alfalfa is shown in Table 6. Rodents destroyed the alfalfa in the irrigated plot

Figure 2. The effect of irrigation and companion crop on the number of legume plants per square foot established during the seeding year, 1956 and 1957. Ladino clover population, without a companion crop, could not be determined and is represented as dashed lines

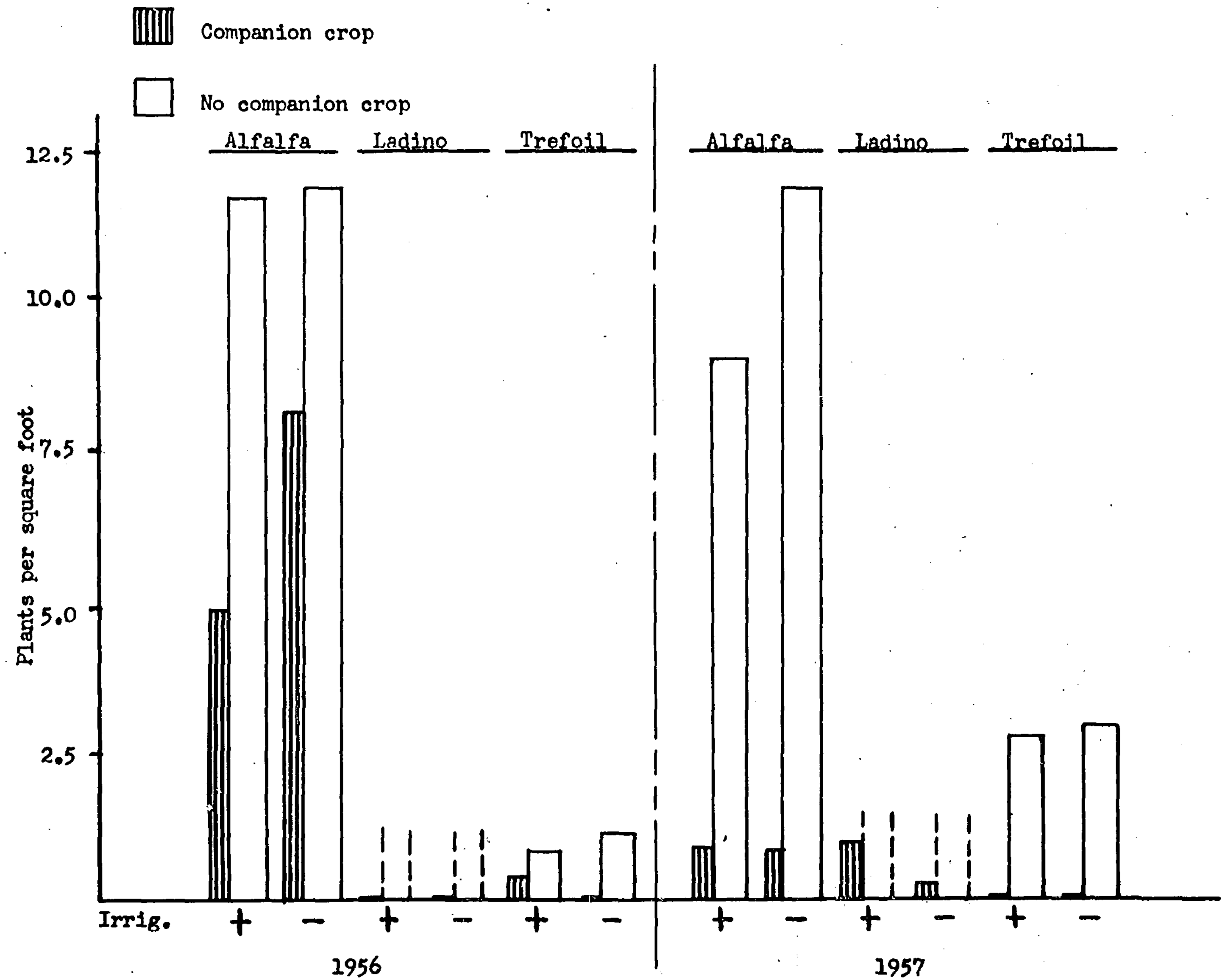

Companion crop
No companion crop
Alfalfa
Ladino
Trefoil
Alfalfa
Ladino
Trefoil
12.5
10.0
7.5
5.0
2.5
Plants per square foot
Irrig.
+
−
+
−
+
−
+
−
+
−
+
−
1956
1957

Figure 3. The effect of irrigation and weeds on the number of legume plants per square foot established during the seeding year, 1956 and 1957. Ladino clover population, without weeds, could not be determined and is shown as dashed lines

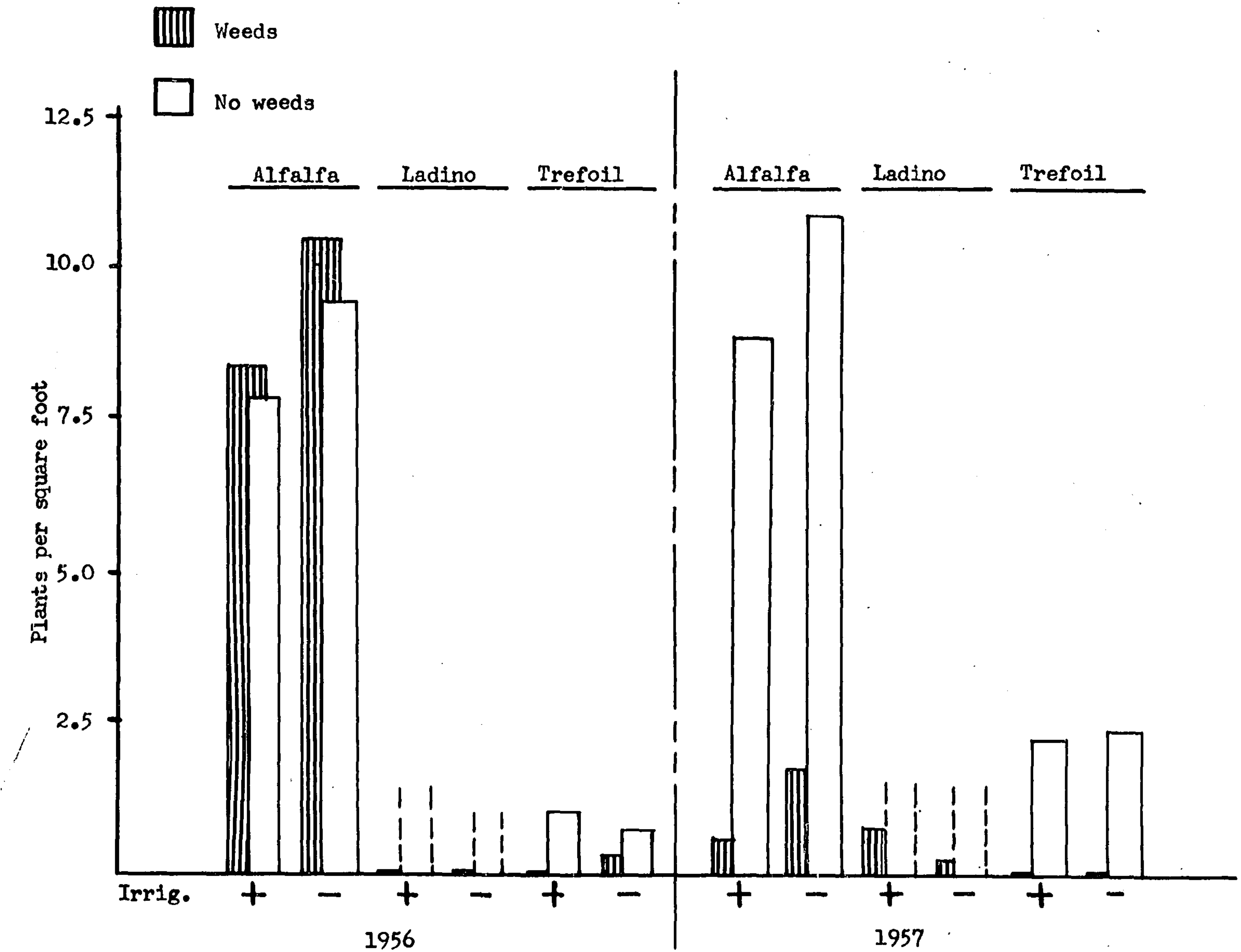

Weeds
No weeds
12.5
10.0
7.5
5.0
2.5
Plants per square foot
Alfalfa
Ladino
Trefoil
Alfalfa
Ladino
Trefoil
Irrig.
+
−
+
−
+
−
+
−
+
−
+
−
1956
1957

Figure 4. The effect of the companion crop and weeds on the number of legume plants per square foot established during the seeding year, 1956 and 1957. Ladino clover population, without weeds and without a companion crop, could not be determined and is represented by dashed lines.

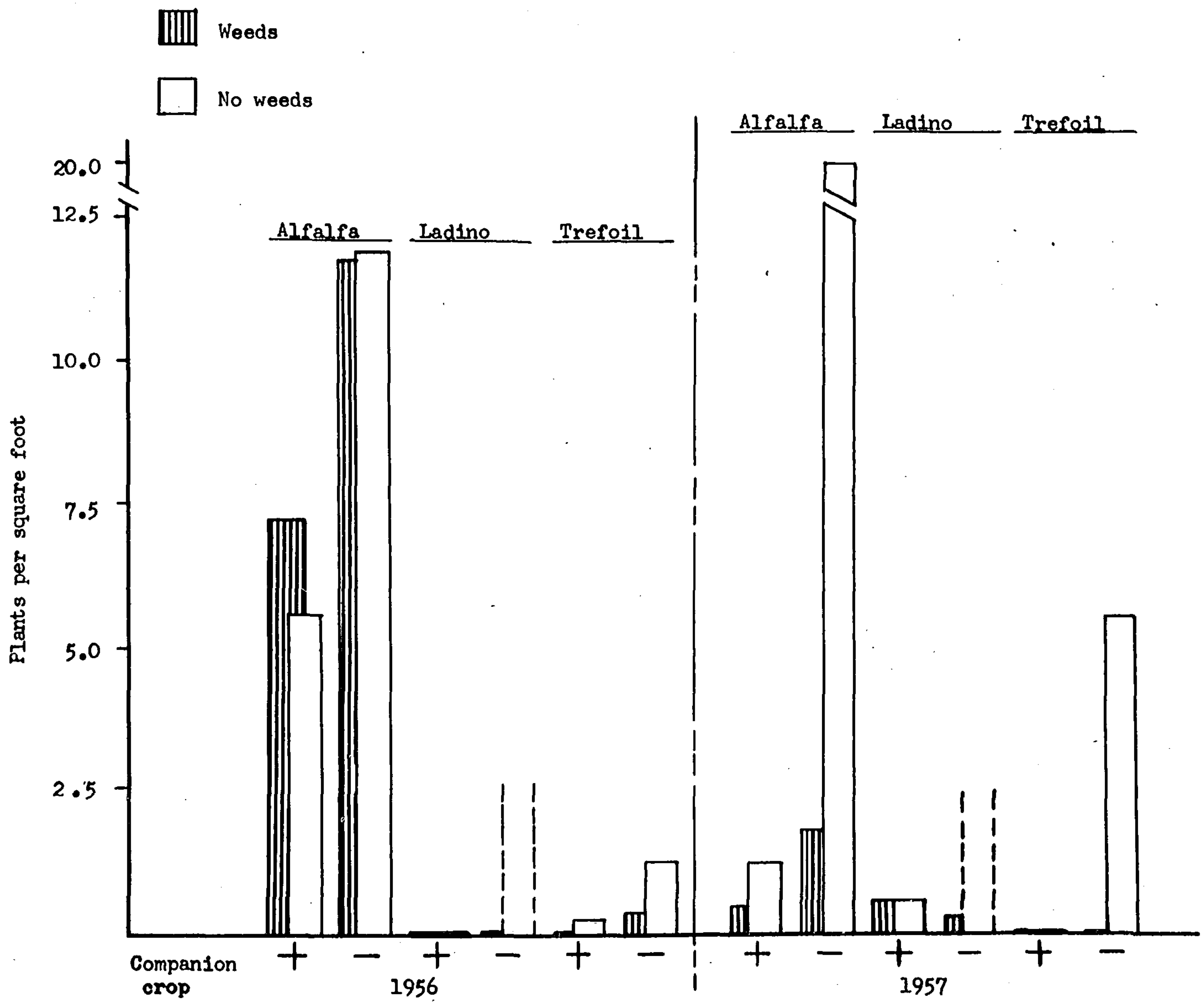

Weeds
No weeds
Plants per square foot
20.0
12.5
10.0
7.5
5.0
2.5
Alfalfa
Ladino
Trefoil
Companion crop
+
−
1956
1957

Figure 5. Weed growth, without a companion crop, at grain harvest on an irrigated plot

Table 6. Analysis of variance, with selected comparisons, of the alfalfa plant population established with and without weeds and with and without irrigation in 1956 and 1957. Stands were evaluated at the end of the growing season

Source of variation	Df	Mean square 1956	Mean square 1957
Replications	3	190.12	127.50
Treatments	7	1,123.48*	7,780.79**
C_1 Companion crop vs. no companion crop	1	6,050.00*	20,402.00**
C_2 Weeds vs. no weeds	1	112.50	17,955.12**
C_3 Irrigation vs. no irrigation	1	741.12	435.12
C_4 Weeds vs. no weeds without companion crop	1	10.56	32,942.25**
C_5 Weeds vs. no weeds with companion crop	1	333.06	64.00
Error	21		114.55
Error	20	329.31	
C_1 x replications	3	301.33	97.67
C_2 x replications	3	544.83	150.46
C_3 x replications	3	112.13	139.13
C_4 x replications	3	287.89	253.75
C_5 x replications	3	417.73	7.50

*Significant at the 5% level.
**Significant at the 1% level.

containing weeds and a companion crop in the 4th replication in 1956. Data for the missing plot were computed for this plot in the manner recommended by Snedecor (41) which accounts for the loss of the 1 degree of freedom in the 1956 analysis.

Treatment effects were found to be significant at the 5% level in 1956 and at the 1% level in 1957. The error term was not homogeneous, as measured by Bartlett's test, therefore the error term was sub-divided and each comparison was tested against the appropriate error term.

The data suggest, and the analysis of variance of the alfalfa counts substantiate, the deleterious effect of the companion crop on the number of plants established of all three legumes. In 1956, the companion crop reduced the number of alfalfa plants established by nearly 50%, Ladino clover was virtually eliminated and birdsfoot trefoil was reduced by 85%. In 1957, alfalfa was reduced by more than 90%, birdsfoot trefoil was nearly eliminated as also was Ladino clover.

Weeds had very little effect when a companion crop was present. Where the companion crop was omitted, the plant counts of alfalfa show that weeds did not significantly affect the number of plants established in 1956 but significantly reduced the number of plants established in 1957. Since it was impossible to determine the number of Ladino clover plants established without weeds and a companion crop, it can only be speculated that the plant population was decreased. With birdsfoot trefoil, weeds without a companion crop significantly reduced the number of plants in 1957 but had no real effect in 1956.

Irrigation had no effect upon the number of legume plants established in either year. The 1956 data show that irrigation resulted in fewer alfalfa plants established when competition either from weeds or companion crop was present. This is only suggestive of a trend since the differences between the irrigated and non-irrigated plots were not significant. With the other legumes, the trend is not evident. The 1957 data show a less clear cut trend although there are such instances. With Ladino clover it is interesting to note that irrigation with competition resulted in more plants established than when irrigation was not applied. These differences, like those of alfalfa in 1956, are not significant.

Higher plant counts in 1956 than in 1957 are due to the response of the companion crop and weeds to the above normal rainfall in 1957. The companion crop significantly reduced stands while weeds had no influence if the companion crop was present. If the companion crop was absent, stands of Ladino clover and birdsfoot trefoil were reduced by weeds in the dry year and all three legumes were reduced in the above normal year. Irrigation had no real influence upon the number of plants established and since fertility was high, neither water nor nutrients can be considered to be limiting in either season. Therefore, light intensity apparently was the growth factor for which competition was most severe. Alfalfa proved to be the most tolerant to low light intensity in the dry season with Ladino clover and birdsfoot trefoil being nearly equal. In the more favorable season, Ladino clover and alfalfa were nearly equal in their tolerance to low light intensity with birdsfoot trefoil being the least tolerant.

The 1958 data (Tables 4 and 5) show the carry-over effect of treatments imposed in 1957. The data show a consistent increase in birdsfoot trefoil plants on the plots where inter-species competition was present the year before. With alfalfa the plant number had decreased by the end of the 1958 season. This is in agreement with the generally accepted response of alfalfa and birdsfoot trefoil during establishment of stands and the growth response during the following season. Where intra-species competition existed, both alfalfa and birdsfoot trefoil declined through the harvest season. The statistical analysis, with selected comparisons, of alfalfa and birdsfoot trefoil is shown in Table 7.

Analysis of the 1958 stand counts shows no significant difference between the number of plants of alfalfa and birdsfoot trefoil present at the end of the first harvest season. While the 1957 data suggested that fewer plants of birdsfoot trefoil would be present in 1958, the inherent slow germination capacity of birdsfoot trefoil make the suggestion

Table 7. Analysis of variance of the number of plants of alfalfa and birdsfoot trefoil present at the end of the harvest season on plots which had been established with and without a companion crop, with and without weeds and with and without irrigation

Source of variation	Df		Mean square	
Replications	3		30.29	
Legumes	1		2.25	
Error (a)	3		17.96	
Treatments	7		269.79**	
C_1 Companion crop vs. no companion crop		1		1,056.25**
C_2 Weeds vs. no weeds		1		495.06**
C_3 Irrigation vs. no irrigation		1		14.06
C_4 Weeds vs. no weeds without a companion crop		1		722.00**
C_5 Weeds vs. no weeds with a companion crop		1		21.12
Treatments x legumes	7		114.07**	
C_1 x legumes		1		182.25*
C_2 x legumes		1		297.56*
C_3 x legumes		1		1.56
C_4 x legumes		1		578.00*
C_5 x legumes		1		0.13
Error (b)	42		10.99	
C_1 x replications		3		25.54
C_2 x replications		3		1.86
C_3 x replications		3		24.69
C_4 x replications		3		2.58
C_5 x replications		3		3.21
C_1 x legumes x replications		3		13.54
C_2 x legumes x replications		3		15.02
C_3 x legumes x replications		3		6.85
C_4 x legumes x replications		3		17.08
C_5 x legumes x replications		3		8.71

*Significant at the 5% level.
**Significant at the 1% level.

invalid.

Significantly fewer alfalfa plants were established on the plots which had a companion crop growing on them the previous season. The data show, and the analysis indicates by a significant legume by comparison treatment interaction, that the response of trefoil was not like that of alfalfa. Analysis of only the trefoil populations indicated no effect due to the companion crop.

Weeds growing on the plots in 1957 had a significant effect on the number of plants present in 1958. Where weeds were grown, significantly fewer plants were present than where weeds had been excluded. A significant treatment comparison by legume interaction suggests that the behavior of the two legumes was not the same and the data show that the reduction in plant population of alfalfa was of much greater magnitude than the reduction in birdsfoot trefoil. The effect of weeds on the plots containing a companion crop was not significant while the effect where a companion crop was absent was highly significant. Fewer plants were established where weeds, without a companion crop, were present than where inter-species competition was absent during the year of establishment. A significant treatment comparison by legume interaction for the effect of weeds without a companion crop suggests the effect was not consistent over both legumes. The data show fewer alfalfa plants were established but the number of birdsfoot trefoil plants was unchanged.

Irrigation, the previous season, had no effect upon the plant population the year following seeding.

With Ladino clover, it was impossible to determine the number of plants present due to the stoloniferous habit of the legume. Therefore visual estimates of the percentage ground cover were made. Analysis of the visual estimates suggests that the companion crop and weeds present the year previously had no influence on ground cover the following year. Where weeds without a companion crop had been grown the year previously, ground cover was significantly lower in comparison to where all inter-species competition was omitted.

The difference between irrigation treatments and no irrigation was significant at the 5% level. This is further evident in the comparison of each pair of treatments where irrigation is the only variable employed. In only one instance did irrigation result in a non-significant comparison. The comparison, irrigation versus no irrigation, with the companion crop absent and weeds present was non-significant.

In summary, the carry-over effect on all legumes was prevalent the year following establishment. However the legumes responded differently. While the companion crop and weeds significantly reduced the plant population of alfalfa and birdsfoot trefoil, the effect of inter-species competition on Ladino clover was not significant. The response of Ladino clover probably was due to the capability of this legume, through its stoloniferous habit, to compensate for the inter-species competition from the previous year. With alfalfa and birdsfoot trefoil, irrigation had no effect but with Ladino clover, the plots which had been irrigated had significantly greater ground cover the year following treatment than the non-irrigated plots. This, also, was undoubtedly due to the effect of irrigation on the creeping habit of the plant during the last half of the establishment year.

Legume yield

Dry matter yields, recorded in grams per treatment summed over the four replications for each legume, are shown in Table 8. The 1956 and 1957 yields were taken during the year of establishment; the 1958 yields were obtained from the 1957 seedings. The treatments shown were imposed only during the year of establishment.

The influence of the companion crop in 1956 and 1957 was so great that obvious differences between the companion crop versus the no companion crop treatments are apparent for all three legumes. The companion crop depressed the yields for all legumes in both years.

Figure 6 is a graphical presentation of the response of the three legumes to weeds and irrigation without a companion

Table 8. Dry matter yield, in grams, of alfalfa, Ladino clover and birdsfoot trefoil harvested twice during the years of establishment, 1956 and 1957, and from the 1957 seedings harvested twice in 1958[a]

Treatment number	1	2	3	4	5	6	7	8
Treatment combinations								
Companion crop	+	+	+	+	-	-	-	-
Weeds	+	+	-	-	+	+	-	-
Irrigation	+	-	+	-	+	-	+	-
				1956				
Alfalfa	2	14	7	26	194	85	648	369
Ladino clover	0	0	0	0	1	0	120	28
Birdsfoot trefoil	1	0	1	0	0	0	324	62
Legume totals	3	14	8	26	195	85	1092	459
				1957				
Alfalfa	2	1	15	5	13	28	365	412
Ladino clover	0	0	1	0	1	0	358	371
Birdsfoot trefoil	0	0	0	0	0	0	653	450
Legume totals	2	1	16	5	14	28	1376	1233
				1958				
Alfalfa	473	339	574	386	646	1036	1255	1261
Ladino clover	380	218	385	128	199	138	567	537
Birdsfoot trefoil	157	74	605	158	150	379	1430	1730
Legume totals	1010	631	1564	672	995	1553	3252	3528

[a]Values for each legume are the sum of four replications.

crop.

Where the companion was not grown, the data in 1956 and Figure 6 suggest a differential response among the legumes to the presence of weeds. The response is not evident in the

Figure 6. Effect of weeds and irrigation without a companion crop on legume yields taken during the year of establishment, 1956 and 1957

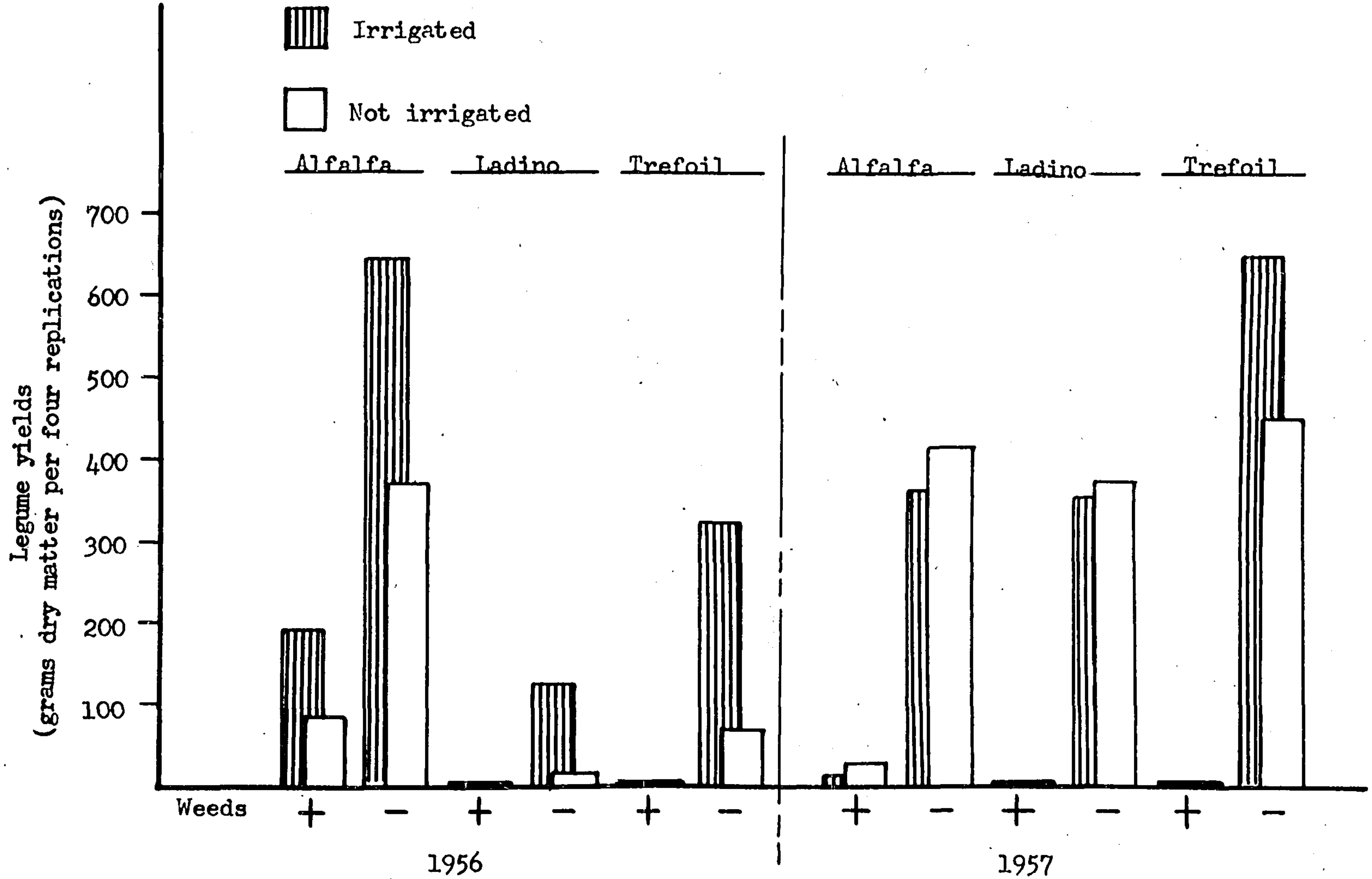

Irrigated
Not irrigated
Alfalfa
Ladino
Trefoil
Alfalfa
Ladino
Trefoil
Legume yields
(grams dry matter per four replications)
700
600
500
400
300
200
100
Weeds
+
−
+
−
+
−
+
−
+
−
+
−
1956
1957

Table 9. Analysis of variance of the dry matter yield of alfalfa grown in 1956 without a companion crop, with and without weeds and with and without irrigation

Source of variation	Df	Mean square	
Replication	3	1577.17	
Treatments	3	15085.17	
C_1 (5, 6 vs. 7, 8)	1		34040.25**
C_2 (5 vs. 6)	1		1485.12
C_3 (7 vs. 8)	1		9730.12**
Error	9	641.44	
C_1 x replications	3		1358.42
C_2 x replications	3		249.12
C_3 x replications	3		316.79

**Significant at the 1% level.

1957 data. In 1956, the dry matter yields of Ladino clover and birdsfoot trefoil were nil while the yield of alfalfa, although small, was of fair magnitude. To evaluate the effect of weeds on alfalfa production, the yields for treatments 5, 6, 7 and 8 were separately analyzed. This analysis is shown in Table 9. Alfalfa yields, like those of Ladino clover and birdsfoot trefoil, were significantly lower where weeds were present than in the weed free plots. Therefore the effect of weeds on alfalfa without a companion crop was deleterious to alfalfa but not of the magnitude of the effect of the companion crop.

The 1957 data indicate the yield depression effect of weeds without a companion crop was as great in a year with above normal rainfall as it was in a dry season. Legume yields in 1957 were essentially zero for all legumes.

Irrigation had no effect in either year in compensating for the competitive effect of the weeds without a companion crop. The 1956 data suggest a positive effect on the alfalfa plots but the statistical analysis in Table 9 indicates the difference is not real.

In general, the effect of the companion crop and weeds was similar for all legumes in both seasons but their effect was greater in 1957, as indicated by weed yields and straw and chaff yields discussed in other sections. As previously stated, the 1957 season had above normal rainfall which resulted in rank growth in both companion crop and weeds. Since the competitive effects of the companion crop or weeds were not alleviated by additional water but rather was increased by irrigation and since the fertility of all plots was high, it can be assumed that the competition in this experiment was for light.

The larger yields from alfalfa suggest and confirm the classification of alfalfa as a very aggressive and competitive legume. It also suggested that in a dry season, the effect of the companion crop on alfalfa is greater than the effect of weeds. With the other legumes, in a dry season, and all three legumes in a wet season, this relationship apparently does not hold.

The yield for the three legumes grown without weeds and a companion crop in both years indicated the necessity of statistical analysis to evaluate the response of the legumes to irrigation. The statistical analysis is shown in Table 10.

Table 10. Analysis of variance of the yields of alfalfa, Ladino clover and birdsfoot trefoil grown in 1956 and 1957 without a companion crop and natural weed infestation but with and without irrigation

Source of variation	Df	Mean square 1956	Mean square 1957
Replications	3	781.82	713.17
Legumes	2	25207.62**	5176.44**
Error (a)	6	2026.57	382.94
Treatments	1	16695.38**	952.08
Treatments x legumes	2	1336.62	2298.14*
Error (b)	9	738.32	394.95
Treatments x replications	3	1426.71	355.13
Treatments x legumes x replications	6	394.12	414.95

*Significant at the 5% level.
**Significant at the 1% level.

Highly significant differences among legumes were found in both years. In 1956, alfalfa yields without irrigation were 6 times larger than birdsfoot trefoil and 13 times larger than Ladino clover. With irrigation, alfalfa yields were twice as large as birdsfoot trefoil and 5 1/2 times larger than Ladino clover. In 1957, a more favorable year, alfalfa yields without irrigation were intermediate between birdsfoot trefoil and Ladino clover. When supplementary water was applied, the yields of Ladino clover and alfalfa were nearly equal and the yield of birdsfoot trefoil was essentially 1.8 times larger than either of the other two legumes. A highly significant treatment effect was found in 1956. During the dry year irrigation resulted in yield increases of 175, 430 and 520% for alfalfa, Ladino clover and birdsfoot trefoil, respectively, over the non-irrigated plots. Irrigation had no significant influence upon legumes during the above normal year.

Figures 7 and 8 show the effect of irrigation on alfalfa and birdsfoot trefoil without a companion crop or weeds.

The legume yields in 1958 showed the influence of the treatments imposed during the year of establishment, <u>i.e.</u> treatment carry-over effect. With two exceptions, the plots which had not had a companion crop nor weeds on them in 1957 yielded over twice as much dry matter in 1958 as the highest yielding plot which had weeds, companion crop, or both, growing on it in 1957. The two exceptions were Ladino clover plots which had been irrigated and contained either a companion crop or companion crop plus weeds. To evaluate the carry-over effect of the treatments the data were statistically analyzed to measure the influence of weeds, companion crop and irrigation. The statistical analysis is shown in Table 11.

Figure 7. Alfalfa growth, at grain harvest, without weeds or companion crop. Irrigated plot on left (L.) and non-irrigated plot on right (R.) (Note 8-inch bricks standing on end)

Figure 8. Irrigated birdsfoot trefoil, at grain harvest time, without weeds or companion crop

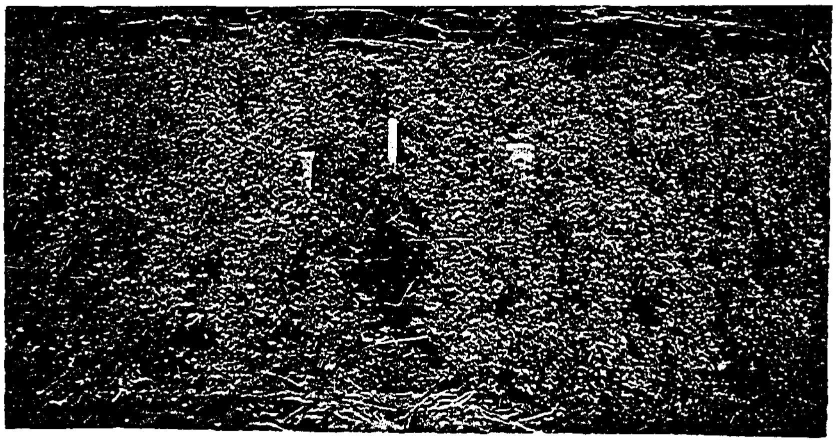


Table 11. Statistical analysis of dry matter production of alfalfa, Ladino clover and birdsfoot trefoil obtained in 1958 from the 1957 seeding which had been grown with and without a companion crop, with and without weeds and with and without irrigation

Source of variation	Df	Mean square	
Replications	3	350.34	
Legumes	2	93,126.35**	
Error (a)	6	3,615.77	
Treatments	7	106,470.95**	
Companion crop vs. no companion crop	1		309,514.59**
Weeds vs. no weeds	1		242,707.59**
Irrigation vs. no irrigation	1		1,989.26
Remainder	4		47,771.31*
Treatments x legumes	14	20,201.26**	
Companion crop x legumes	2		104,779.14**
Weeds x legumes	2		57,320.70**
Irrigation x legumes	2		3,154.98
Remainder x legumes	2		7,140.40**
Error (b)	63	2,473.35	
Companion crop x replications	3		1,468.74
Weeds x replications	3		4,772.24
Irrigation x replications	3		4,270.57
Remainder x replications	12		10,304.01
Companion crop x legumes x replications	6		3,180.94
Weeds x legumes x replications	6		1,862.91
Irrigation x legumes x replications	6		6,068.28
Remainder x legumes x replications	24		1,415.23

*Significant at the 5% level.
**Significant at the 1% level.

This analysis shows a highly significant effect among legumes, among treatments and legume by treatment interaction. The significant level of the latter two resulted when they were tested against a pooled error. Significant differences, at the 1% level, were found for the companion crop versus no companion crop, weeds versus no weeds and the companion crop by legume and weeds by legume interactions when tested against the appropriate error term. Neither irrigation nor irrigation by legume interactions were significant. The treatment remainder was significant at the 5% level and the remainder by legume interaction was significant at the 1% level, when tested against the appropriate error term. Because the remainder and remainder by legume interaction were significant and because Error (b) was not homogeneous, as measured by Bartlett's test, three sets of orthogonal comparisons were set up for the treatments using the effects of the companion crop, weeds or irrigation as the first comparison in each set. One set of these comparisons, using companion crop versus no companion crop as the first comparison, is shown as an illustration in Table 12.

The analysis indicates a highly significant difference among legumes. The data show the general superiority of alfalfa to outyield the other legumes. The data indicate that inter-species competition is less severe with alfalfa than either Ladino clover or birdsfoot trefoil. Where competition is most severe, i.e. both companion crop and weeds present, Ladino clover responded somewhat more favorably than birdsfoot trefoil but where either the companion crop or weeds were omitted from the treatments during the seeding year, the

Table 12. Statistical analysis of dry matter production of alfalfa, Ladino clover and birdsfoot trefoil obtained in 1958 from the 1957 seeding which had been grown with and without a companion crop, with and without weeds and with and without irrigation

Source of variation	Df		Mean square	
Replications	3		350.34	
Legumes	2		93,126.35**	
Error (a)	6		3,615.77	
Treatments	7		106,470.95**	
C_1 (1,2,3,4 vs. 5,6,7,8)		1		309,514.59**
C_2 (1,2 vs. 3,4)		1		7,375.52
C_3 (1 vs. 2)		1		5,985.04
C_4 (3 vs. 4)		1		33,152.67
C_5 (5,6 vs. 7,8)		1		373,121.33**
C_6 (5 vs. 6)		1		12,973.00
C_7 (7 vs. 8)		1		3,174.00
Treatments x legumes	14		20,201.26**	
C_1 x legumes		2		52,389.57**
C_2 x legumes		2		6,067.02
C_3 x legumes		2		200.54
C_4 x legumes		2		2,248.79
C_5 x legumes		2		69,877.02**
C_6 x legumes		2		6,529.62
C_7 x legumes		2		4,096.50
Error (b)	63		2,473.35	
C_1 x replications		3		1,468.74
C_2 x replications		3		2,377.47
C_3 x replications		3		1,544.71
C_4 x replications		3		4,993.11
C_5 x replications		3		4,393.72
C_6 x replications		3		1,408.94
C_7 x replications		3		2,207.56
C_1 x legumes x replications		6		3,180.94
C_2 x legumes x replications		6		2,487.21
C_3 x legumes x replications		6		2,919.21
C_4 x legumes x replications		6		1,248.24
C_5 x legumes x replications		6		1,532.24
C_6 x legumes x replications		6		3,426.90
C_7 x legumes x replications		6		1,978.56

**Significant at the 1% level.

response of birdsfoot trefoil tended to be more favorable than the response of Ladino clover. Where only intra-species competition was permitted in the seeding year, the dry matter production of the legumes the year after seeding indicate birdsfoot trefoil to be the superior legume with alfalfa close to birdsfoot trefoil and Ladino clover third in rank.

Where the companion crop versus no companion crop was the first comparison, a highly significant difference was found. The data show that where the companion crop was grown in 1957, significantly lower yields were obtained in 1958. The magnitude of the response of all legumes was not the same since a highly significant legume by comparison interaction was found. The data show that alfalfa yields in 1958 were depressed 58% from the influence of the companion crop in 1957, based on the 1958 yield of alfalfa grown without a companion crop in 1957. Yield reductions for Ladino clover and birdsfoot trefoil were 23% and 73% respectively. This is also indicative of the relative competitive capacity of alfalfa and birdsfoot trefoil and at the same time shows the capacity of Ladino clover to compensate for the influence of the companion crop by becoming thicker through its stoloniferous habit of spreading.

In the same analysis, the comparison of the effect of weeds without a companion crop was highly significant. Weeds depressed the yields of all legumes and a highly significant treatment comparison, effect of weeds without a companion crop, by legume interaction was found. The data indicate that weeds in 1957 depressed the 1958 yields of alfalfa by 33%, Ladino clover by 69% and birdsfoot trefoil by 87%.

All comparisons of the effect of irrigation were non-significant.

The analysis for testing the effect of weeds as the first orthogonal comparison showed a highly significant difference due to weeds and a highly significant effect of the companion crop where weeds were absent. While the carry-over effect of weeds and the companion crop depressed the dry matter production in 1958, the response of all legumes was not of the same magnitude as indicated by highly significant treatment comparisons, weeds and companion crop, by legume interactions. Weeds depressed the yield of alfalfa by 28% Ladino clover by 42% and birdsfoot trefoil by 81%. The companion crop, in the absence of weeds, depressed alfalfa by 62%, Ladino clover by 54% and birdsfoot trefoil by 76%. The suggestion is made therefore, that the competition between alfalfa and the companion crop in the year of establishment, and reflected in the first harvest year, is more severe than the competition with weeds. With the other legumes, however, the competition with weeds is more severe than the competition of the companion crop. These were the same findings obtained with the previously mentioned analysis.

The effect of the companion crop, in the presence of weeds, was not significant. However a treatment, effect of companion crop with weeds, by legume interaction was highly significant. Alfalfa and birdsfoot trefoil were depressed by 50 and 65 per cent respectively and Ladino clover was increased by 178% by the companion crop when weeds were present. Why the yield of Ladino clover is increased is probably due to the stoloniferous habit of the legume in the absence of weed and companion crop competition during the second half of the seeding year.

As with the previous analysis, comparisons of irrigation versus no irrigation were not significant.

Where irrigation versus no irrigation was the first orthogonal comparison, no significant differences due to irrigation were found. The effect of the companion crop on the irrigated plots during the year of establishment significantly reduced (5% level) the yield of the legumes. On the plots which did not receive irrigation, the carry-over effect of the companion crop resulted in differences significant at the 1% level.

The effect of the companion crop on both the irrigated and non-irrigated plots differed among legumes as was indicated by highly significant treatment comparison by legume interactions. Where irrigation had been applied in 1957, the effect of the companion crop, when compared to the plots which had not had a companion crop present, reduced the yield of alfalfa and birdsfoot trefoil by 50% and had no influence upon Ladino clover. In the instances when no irrigation had been applied in 1957, the companion crop reduced the yield of alfalfa by approximately 76%, the yield of Ladino clover by 50% and the yield of birdsfoot trefoil by 89%.

The effect of weeds on the plots containing a companion species was not significant. However, where the companion crop had been omitted, the effect of weeds was significant at the 5% level when irrigation was omitted and significant at the 1% level when irrigation was applied. Yield decreases were observed in both instances. Highly significant treatment comparison, effect of weeds with and without a companion crop, by legume interactions were found in both instances. The carry-over effect of weeds, grown in 1957 on plots which were not irrigated and the companion crop was omitted, depressed the yields of alfalfa, Ladino clover and birdsfoot trefoil by 17, 74 and 78% respectively, as compared to the plots treated in the same way except that weeds were removed. On the irrigated plots handled in the same way, the magnitude of the effect of the yield depression due to weeds was 51% for alfalfa, 65% for Ladino clover and 89% for birdsfoot trefoil.

In general, the influence of the treatments imposed during the seeding year was manifested in the yields obtained during the first harvest year. The data indicate alfalfa to be higher yielding than either Ladino clover or birdsfoot trefoil and that the growth responses of the latter two legumes to be quite similar. The companion crop and weeds significantly reduced yields of all legumes while irrigation had no effect. Concerning only the influence of the companion species, the legumes responded differently in that Ladino clover yields were depressed the least and birdsfoot trefoil yields depressed the most with alfalfa intermediate between the two. Where the companion crop was grown, weeds had no influence but where the companion crop was absent weeds significantly depressed yields. In this instance, alfalfa was depressed the least, Ladino clover intermediate and birdsfoot trefoil the most. Concerning the influence of weeds, an overall decrease in yield of the legumes was observed. Where weeds were permitted to grow, the companion crop exerted no significant effect although the response among legumes differed. Weeds plus a companion crop, as compared to weeds without a companion crop, increased the yield of Ladino clover but decreased the yields of alfalfa and birdsfoot trefoil. Where weeds were omitted, the companion crop decreased the yield of Ladino clover the least and birdsfoot trefoil the most. Alfalfa was intermediate.

<u>Weed yield</u>

Dry matter yields, recorded in grams per plot summed over the four replications for each legume and treatment are shown

Table 13. Dry matter yield, in grams, of weeds harvested twice during each year of establishment of alfalfa, Ladino clover and birdsfoot trefoil in 1956 and 1957, and from the 1957 seedings harvested twice in 1958[a]

Treatment number	1	2	3	4	5	6	7	8
Treatment combinations								
Companion crop	+	+	+	+	-	-	-	-
Weeds	+	+	-	-	+	+	-	-
Irrigation	+	-	+	-	+	-	+	-
			1956					
Alfalfa	911	215	61	30	1218	666	4	2
Ladino clover	1183	248	62	49	1396	715	2	9
Birdsfoot trefoil	670	388	83	27	1458	919	3	8
Legume totals	2764	851	206	106	4072	2300	9	19
			1957					
Alfalfa	653	339	49	62	1639	1671	14	7
Ladino clover	619	487	60	71	1985	1782	10	88
Birdsfoot trefoil	524	459	35	72	1783	2101	13	2
Legume totals	1796	1285	144	205	5407	5554	37	97
			1958					
Alfalfa	586	754	554	741	595	418	42	23
Ladino clover	418	725	510	1181	527	653	26	34
Birdsfoot trefoil	676	738	516	990	787	945	250	273
Legume totals	1680	2217	1580	2912	1909	2016	318	330

[a]Values are the sum of four replications.

in Table 13.

In accordance with the original plan of the experiment, weeds were removed on four treatments during the year of establishment of the legumes while a natural weed infestation was permitted to exist on the other four treatments. Within those plots where the weeds were removed, the yield of weeds, although small, was higher where the companion crop was grown than where it was omitted. This was due to the fact that as the small grain approached maturity, it became increasingly difficult to remove the weeds without undue lodging of the small grain.

Because of the obvious differences in weed yield between plots which had a natural weed infestation and those on which the weeds were removed, only those in which weeds were permitted to grow were statistically analyzed. The analysis of the 1956 data, with selected comparisons, is shown in Table 14.

No differences in weed yields among legumes were found. The data suggest that none of the legumes gave serious competition to the weed growth. Treatments and treatment by legumes interaction were highly significant and significant respectively when tested against the pooled error term. However, the error term was not homogeneous and when tested against the appropriate error term, only the treatments were highly significant.

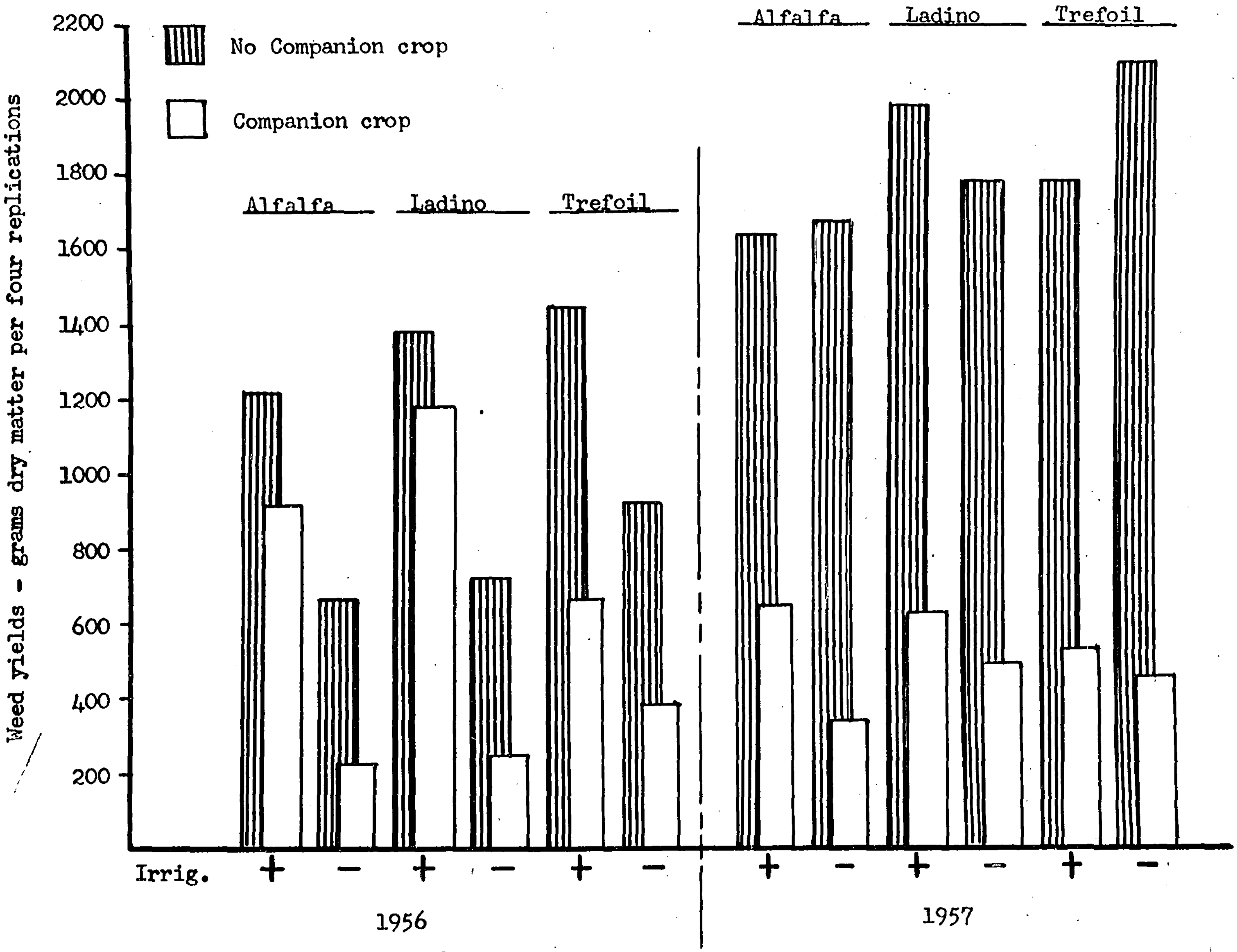
Within the treatments, a highly significant effect due to the companion crop was found. Where the companion crop was grown, significantly lower weed yields were obtained. (See Figure 9) This serves to indicate the weed control

Table 14. Statistical analysis, with selected comparisons, of weed yields from weeds grown in competition with three legumes and with and without irrigation in 1956

Source of variation	Df		Mean square	
Replications	3		864.73	
Legumes	2		2,726.60	
Error (a)	6		1,752.68	
Treatments	7		201,884.85**	
C_1 (1,2 vs. 5,6)		1		158,355.18**
C_2 (1 vs. 2)		1		152,482.04**
C_3 (5 vs. 6)		1		130,832.66**
C_4 (1,5 vs. 2,6)		1		282,747.00**
C_5 (1 vs. 5)		1		71,286.00
C_6 (2 vs. 6)		1		87,362.67**
Treatments x legumes	14		3,472.86*	
C_1 x legumes		2		7,595.05
C_2 x legumes		2		13,644.30
C_3 x legumes		2		770.30
C_4 x legumes		2		9,970.28
C_5 x legumes		2		11,894.62
C_6 x legumes		2		320.35
Error (b)	63		1,673.40	
C_1 x replications		3		4,174.14
C_2 x replications		3		3,733.15
C_3 x replications		3		2,666.78
C_4 x replications		3		1,691.97
C_5 x replications		3		7,445.89
C_6 x replications		3		1,500.61
C_1 x legumes x replications		6		3,191.19
C_2 x legumes x replications		6		2,856.56
C_3 x legumes x replications		6		4,787.23
C_4 x legumes x replications		6		5,471.71
C_5 x legumes x replications		6		4,677.51
C_6 x legumes x replications		6		627.22

*Significant at the 5% level.
**Significant at the 1% level.

Figure 9. Effect of irrigation and companion crop on weed yields taken during the year of legume establishment, 1956 and 1957


Weed yields - grams dry matter per four replications
2200
2000
1800
1600
1400
1200
1000
800
600
400
200
No Companion crop
Companion crop
Alfalfa
Ladino
Trefoil
Alfalfa
Ladino
Trefoil
Irrig.
+
-
+
-
+
-
+
-
+
-
+
-
1956
1957

capacity of the companion oat crop. The analysis of the 1957 data indicated the same relationship in the more favorable year.

Within the plots where the companion crop was grown, the comparison of irrigation versus no irrigation was highly significant. Where irrigation was applied, weed yields were significantly higher than where irrigation was omitted. During the more favorable season of 1957, the effect of irrigation significantly increased weed yields.

A highly significant effect due to irrigation was observed on the plots where the companion crop was omitted. Yields were nearly doubled when irrigation was applied. Analysis of the 1957 data indicated no effect of irrigation on weed growth in plots on which the companion crop was omitted.

The weed yields on the plots which were irrigated were significantly higher (1% level of significance) than the non-irrigated plots. In 1957 this was not the case. The weed yield of the irrigated plots containing a companion crop, when compared to those not containing a companion crop, were not significantly different in 1956 but highly significant in 1957. During the 1956 season, the irrigated plots containing the companion crop yielded slightly less than the plots without a companion crop but this serves only to indicate a trend. In 1957, the lack of competition between the companion crop and the weeds and the abundant water supply through normal rainfall and irrigation was manifested in weed yields two to three times larger than where the companion crop was excluded from the irrigated plots.

A highly significant weed yield depression occurred due to the effect of the companion crop on the non-irrigated plots during both seasons. Weed yield was 3 to 5 times larger where the companion crop was omitted.

It is interesting to note that the effect of irrigation where the companion crop was grown was highly significant in 1957 and significant at the 5% level in 1956 while the effect of the companion crop on the irrigated plots was not significant in 1957 and highly significant in 1956. The suggestion is made that when the season is dry, as in 1956, weeds compete very favorably for supplementary water and where the season is above normal and additional water is applied, the competition of weeds and small grain is less pronounced. On the other hand, where moisture is adequate, as the irrigated plots would indicate, the competition between the companion crop and weeds was negligible in 1956 but where moisture was abundant, as in the 1957 season, weeds competed favorably for the excess water. This is in agreement with the statement of Blackman (3) that wet years favor weed growth.

A word of explanation is necessary concerning the weed growth in 1957 on the Ladino clover plots upon which both weeds and companion crop were omitted. The data indicate weed growth was 8 times larger where irrigation was omitted than where it was included as part of the treatment. After August 7, foxtail, Setaria spp. invaded the plots and was masked by the taller growing Ladino clover. The bulk of the weed yield shown for this treatment was made up of foxtail plants three to four inches high. The weed ingress of the same magnitude did not occur on the other Ladino clover plots.

The 1958 weed yields show the carry-over effect of the treatments imposed in 1957. With the exception of the plots where both weeds and a companion crop had been omitted in 1957, the effect of the treatments was virtually non-existant. Where both weeds and the companion crop were omitted in 1957, weed yields in 1958 were very low on the alfalfa and Ladino clover plots. On the birdsfoot trefoil plots, weed yields were considerably higher but did not reach the magnitude where weeds, the companion crop, or both, were permitted to grow the previous year. The data suggest the competitive inability of birdsfoot trefoil the year after seeding while alfalfa and Ladino clover can compete very successfully. This is in agreement with the competitive ability rating of the legumes by Blaser, et al. (8).

The analysis of the 1958 weed yields showing only the significant treatment effects is shown in Table 15. It is interesting to note that with one exception, the significant

Table 15. Statistical analysis with selected comparisons of dry matter yields of weeds obtained in 1958 from seedings grown in competition with three legumes and with and without irrigation in 1957 (Only significant treatment effects are shown)

Source of variation	Df	Mean square	
Replications	3	550.97	
Legumes	2	18,124.83	
Error (a)	6	6,103.98	
Treatments	7	67,029.92**	
C_1 (1,2,3,4 vs. 5,6,7,8)	1		151,686.00**
C_2 (5,6 vs. 7,8)	1		223,723.52**
C_3 (1,2,5,6 vs. 3,4,7,8)	1		74,928.38*
C_4 (3,4 vs. 7,8)	1		307,840.33**
C_5 (5 vs. 7)	1		105,470.04**
C_6 (2,4 vs. 6,8)	1		161,356.02**
C_7 (2 vs. 4)	1		20,126.04*
C_8 (6 vs. 8)	1		118,441.50**
Treatment x legumes	14	4,198.81	
C_1 x legumes	2		8,646.22
C_2 x legumes	2		1,100.28
C_3 x legumes	2		2,550.22
C_4 x legumes	2		6,684.52
C_5 x legumes	2		88.66
C_6 x legumes	2		8,602.52
C_7 x legumes	2		6,912.54
C_8 x legumes	2		2,702.38
Error (b)	63	4,934.52	
C_1 x replications	3		1,848.19
C_2 x replications	3		3,483.08
C_3 x replications	3		5,453.18
C_4 x replications	3		1,571.17
C_5 x replications	3		1,588.82
C_6 x replications	3		1,701.74
C_7 x replications	3		1,072.93
C_8 x replications	3		2,618.83
C_1 x legumes x replications	6		5,960.25
C_2 x legumes x replications	6		5,563.99
C_3 x legumes x replications	6		7,166.11
C_4 x legumes x replications	6		3,250.27
C_5 x legumes x replications	6		5,973.11
C_6 x legumes x replications	6		3,706.58
C_7 x legumes x replications	6		2,862.60
C_8 x legumes x replications	6		2,633.04

*Significant at the 5% level.
**Significant at the 1% level.

treatments include treatment 7, treatment 8 or both. The one exception, comparison 7, which was a comparison of weeds versus no weeds on the non-irrigated plots which had a companion crop, was significant at the 5% level. In this instance, the plots which contained weeds in 1957 yielded less weed dry matter in 1958 than the 1958 yields of the plots which did not contain weeds in 1957. This was probably due to the fact that the competition of both companion crop and weeds in 1957 resulted in less vigorous plants in 1958 than where competition from only the companion crop was present in 1957.

Some comparisons involving treatments 7 and 8 were not significant. The comparison of treatment 7 versus treatment 8, the comparison of irrigation versus no irrigation and the comparison of the companion crop versus no companion crop on the irrigated plots were not significant.

In general, where weeds were present, the companion crop depressed the weed yield during both years while irrigation increased the weed yield during the dry season but did not significantly change it during the normal season. Irrigation significantly increased weed yield where the companion crop was grown during both seasons but where the companion crop was absent, significant increases were observed only during the dry season. On the irrigated plots, the companion crop decreased the weed yields only during the season with above normal rainfall, which suggests the ability of the companion crop to compete more favorably with weeds during an abnormal season. On the non-irrigated plots, the companion crop decreased the weed yield during both seasons.

The carry-over effect of the treatments was essentially non-existent during the first harvest year. The only instances in which weed yield was greatly reduced was on the plots which had neither weeds nor companion crop on them the previous year.

Grain yield

The yields of oat grain for treatment combinations for the two years are shown in Table 16. The values shown are the weight, in grams, summed over the four replications, for each treatment combination with each legume.

Oat grain yields were somewhat higher in 1957 than in 1956. This probably was due to the more favorable growing season in 1957.

The data were analyzed statistically for both seasons and the analysis, with selected comparisons, is shown in Table 17.

The analysis shows there was no treatment effect when the test of significance was made against the pooled error term. Since the error term was not homogeneous, as measured by Bartlett's test, the error was sub-divided and all comparison effects and comparison by legume interactions were tested

Table 16. Oat yields, in grams, for four treatment combinations; with and without weeds and with and without irrigation, grown with alfalfa, Ladino clover and birdsfoot trefoil, harvested in 1956 and 1957[a]

Treatment number	1	2	3	4
Treatment combinations				
Weeds	+	+	-	-
Irrigation	+	-	+	-
	1956			
Alfalfa	89	194	193	209
Ladino clover	162	171	192	176
Birdsfoot trefoil	163	151	137	152
Legume totals	414	516	522	537
	1957			
Alfalfa	233	174	212	226
Ladino clover	149	298	224	165
Birdsfoot trefoil	191	217	202	200
Legume totals	573	689	638	591

[a]Values shown are the sum of the four replications.

against the appropriate error term.

Generally, weeds had no effect in either year. A treatment comparison, effect of weeds on the non-irrigated plots, by legume interaction was significant in 1957. The data show that weeds increased grain yields on the Ladino clover and birdsfoot trefoil plots while they decreased the yield on the alfalfa plots. This can be attributed to experimental error since the legumes were not a competitive force at this time of the season.

Table 17. Analysis of variance of grain yields obtained with and without irrigation, with and without weeds and with three legumes during 1956 and 1957

Source of variation	Df	Mean squares 1956		1957	
Replications	3	222.69		962.96	
Legumes	2	172.76		20.64	
Error (a)	6	53.50		241.01	
Treatments	3	263.19		255.13	
1,2 vs. 3,4	1		346.69		22.69
1,3 vs. 2,4	1		285.19		99.19
1 vs. 2	1		433.50*		560.67*
2 vs. 4	1		18.38		400.17
Treatments x legumes	6	284.92[a]		558.68**[b]	
Error (b)	27	152.52		146.77	
1,2 vs. 3,4 x reps	3		508.52		30.13
1,3 vs. 2,4 x reps	3		46.46		31.41
1 vs. 2 x replications	3		15.83		24.77
2 vs. 4 x replications	3		184.59		43.39

*Significant at the 5% level.
**Significant at the 1% level.

[a]Non-significant comparison x legume interactions when tested against the appropriate error term.

[b]Significant at the 1% level when tested against a pooled error term. Comparison 1 vs. 2 x legumes and 2 vs. 4 by legumes were significant at the 5% level when tested against the appropriate error term.

Irrigation was shown, by the analysis, to have no influence upon grain yields during either season. However, if only the plots which had weeds on them are considered, irrigation resulted in a significant (5% level) decrease in grain yield. This is in agreement with Blackman (3). A significant treatment comparison, effect of irrigation on weed infested plots, by legume interaction was found for the same treatment in 1957. The data show that in 1957, irrigation of the plots with natural weed infestations resulted in increased grain yields on the alfalfa plots and decreased yields on the Ladino clover and birdsfoot trefoil plots. This is undoubtedly due to experimental error since the legumes had not yet become a competitive force and all plots were treated alike.

In general, weeds and irrigation had no effect upon grain yields in either season. However, a significant irrigation by weeds interaction suggested that irrigation reduced grain yields where weeds were present.

Weight per 1000 kernels

The weights per 1000 kernels of oats grown under the various treatment combinations are shown in Table 18. Each value shown represents the sum, in grams, of the 4 replications of oats grown in competition with each legume for each treatment combination.

Seed produced in 1957 were slightly heavier than the seed in 1956. This probably was due to the early irrigation and to the more favorable growing conditions in 1957. Seed weight of oats seeded to different legumes was relatively constant suggesting that the legumes did not influence seed weight.

Table 18. Weight per 1000 kernels, in grams, of oats with alfalfa, Ladino clover and birdsfoot trefoil grown with and without weeds and with and without irrigation in 1956 and 1957[a]

Treatment number	1	2	3	4
Treatment combinations				
Weeds	+	+	-	-
Irrigation	+	-	+	-
	1956			
Alfalfa	90.3	84.2	94.7	84.6
Ladino clover	87.1	81.3	98.2	88.3
Birdsfoot trefoil	87.8	81.3	89.1	78.6
Legume totals	265.2	246.8	282.0	251.5
	1957			
Alfalfa	98.2	95.8	95.5	92.4
Ladino clover	97.1	103.7	95.6	99.5
Birdsfoot trefoil	93.5	99.9	91.5	96.0
Legume totals	288.8	299.4	282.6	287.9

[a]Values shown are the sum of the four replications.

The statistical analysis, with selected comparisons, is shown for both years in Table 19.

Experimental error was not homogeneous; therefore the error was sub-divided and all tests of significance were made against the appropriate error term.

A highly significant treatment effect was found in 1956 but not in 1957 when tested against the pooled error. Individual comparisons showed that the significant effect was due almost entirely to the effect of irrigation.

Table 19. Analysis of variance of weight per 1000 kernels of oats grown with and without weeds, with and without irrigation and with three legumes during 1956 and 1957

Source of variation	Df		Mean squares 1956		Mean squares 1957	
Replications	3		6.36		14.62	
Legumes	2		6.48		4.41	
Error (a)	6		3.19		9.98	
Treatments	3		20.72**		4.14	
1,2 vs. 3,4		1		9.46		6.61
1,3 vs. 2,4		1		49.61**		5.26
1 vs. 2		1		13.98*		4.62
2 vs. 4		1		0.87		5.50*
Treatments x legumes	6		2.11[a]		1.85[a]	
Error (b)	27		1.84		2.32	
1,2 vs. 3,4 x reps		3		1.76		0.77
1,3 vs. 2,4 x reps		3		1.94		3.05
1 vs. 2 x replications		3		0.82		3.00
2 vs. 4 x replications		3		3.13		0.35

*Significant at the 5% level.
**Significant at the 1% level.

[a]Non-significant comparison x legume interactions when tested against the appropriate error term.

Irrigation had a highly significant effect upon seed weight during the dry season but had no effect in the season of above normal rainfall. During the dry season irrigation resulted in heavier seed. The effect of irrigation on plots containing weeds was significant at the 5% level in 1956. The data show that irrigation resulted in increasing seed weight. The same result was obtained in the comparison of irrigation versus no irrigation on the weed free plots. That comparison is not shown in the analysis in Table 19.

Weeds, in general, had no effect upon seed weight. However, if the non-irrigated plots are considered, weeds significantly increased the seed weight during the season of above normal rainfall. The comparison of weeds on the irrigated plots, not shown in the analysis, was not significant in either year.

In general, irrigation resulted in heavier seed produced by the oat companion crop during the dry season. Irrigation of the weed infested plots significantly increased the weight per 1000 kernels, during the dry season and weeds on the non-irrigated plots increased the seed weight during the season of above normal rainfall.

Straw and chaff yield

The dry matter yield, in grams, of straw and chaff from the oat companion crop for each treatment combination and with each of 3 legumes is shown in Table 20. The values reported are the treatment sums over the four replications for each legume.

Heavier yields of straw and chaff were harvested in 1957 than in 1956. This was the manifestation of the above normal rainfall in 1957 in contrast to the dry season of 1956.

The data were analyzed statistically to evaluate the effects of weeds and irrigation. The analysis, with selected

Table 20. Dry matter yields, in grams, of straw and chaff grown with alfalfa, Ladino clover and birdsfoot trefoil, with and without weeds and with and without irrigation, in 1956 and 1957[a]

Treatment number	1	2	3	4
Treatment combination				
Weeds	+	+	-	-
Irrigation	+	-	+	-
	1956			
Alfalfa	159	343	258	342
Ladino clover	240	253	301	284
Birdsfoot trefoil	251	285	244	282
Legume totals	650	881	803	908
	1957			
Alfalfa	1008	848	927	942
Ladino clover	740	1155	841	800
Birdsfoot trefoil	871	853	852	1014
Legume totals	2619	2856	2620	2756

[a]Values shown are the sum of the four replications for each treatment.

comparisons, is shown in Table 21.

The analysis of the straw and chaff yields showed a highly significant treatment effect in 1956 but no treatment effect in 1957 when tested against the pooled error. However, the error term was not homogeneous, as measured by Bartlett's test, therefore the error term was sub-divided and all tests of significance were made against the appropriate error term.

Generally, weeds had no effect on straw and chaff yields.

Table 21. Analysis of variance, with selected comparisons, of straw and chaff yields obtained with and without weeds and with and without irrigation in 1956 and 1957

Source of variation	Df		Mean squares 1956	1957
Replications	3		213.67	6,301.74
Legumes	2		25.38	592.26
Error (a)	6		213.04	4,088.14
Treatments	3		1,119.28**	1,105.08
C_1 1,2 vs. 3,4		1	675.00	204.19
C_2 1,3 vs. 2,4		1	2,352.00*	2,898.52
C_3 1 vs. 2		1	2,223.38**	2,340.38
C_4 2 vs. 4		1	30.38	416.67
Treatments x legumes	6		545.65	5,045.88
C_1 x legumes		2	230.21	2,549.49
C_2 x legumes		2	1,230.96	4,226.96
C_3 x legumes		2	1,087.06*	11,214.12
C_4 x legumes		2	45.50	9,840.54*
Error (b)	27		241.71	2,455.84
C_1 x replications		3	583.19	700.52
C_2 x replications		3	118.44	988.08
C_3 x replications		3	84.26	2,070.82
C_4 x replications		3	529.70	552.56
C_1 x legumes x replications		6	238.15	2,439.67
C_2 x legumes x replications		6	264.46	2,652.01
C_3 x legumes x replications		6	154.86	3,714.07
C_4 x legumes x replications		6	239.33	1,203.10

*Significant at the 5% level.
**Significant at the 1% level.

The effect of weeds on the non-irrigated plots, as shown in the analysis, was not significant. The same comparison of weeds versus no weeds on the irrigated plots, not shown in the analysis, also was not significant. A significant treatment comparison, effect of weeds on the non-irrigated plots, by legume interaction was significant in 1957. The data show weeds increased the straw and chaff yields on the Ladino clover and birdsfoot trefoil plots but decreased the straw and chaff yields on the alfalfa plots. This is explained on the basis of experimental error since all plots were treated in the same way.

Irrigation had a significant effect in a dry season (1956) and no effect in the season of above normal rainfall (1957). In 1956 the irrigated plots yielded only 81% as much straw and chaff as the non-irrigated plots. In 1957, yields of the irrigated plots were lower than the non-irrigated plots but the difference was not significant. Where irrigation was applied to oats with weeds in 1956, the straw and chaff yield was only 75% as large as the yield of the non-irrigated plots, a highly significant difference. A significant treatment comparison, the effect of irrigation with weeds, by legume interaction was found which points out that irrigation on the alfalfa plots reduced straw and chaff yields by over 50% while with the other legumes, only a small decrease occurred. The differences in straw and chaff due to irrigation on the weed plots is due to the increased competition from the weeds with the companion crop.

In general, weeds had no effect upon straw and chaff yields in either season. Irrigation in the presence of weeds decreased the yield of straw and chaff by a significant amount in the dry season but had no effect during the season of above normal rainfall.

Greenhouse Study

Because of the limitations of greenhouse space and size of the metal shades, this portion of the study was not replicated.

The effect of light intensity and irrigation on several attributes of alfalfa, Ladino clover and birdsfoot trefoil are presented in Table 22. Each value given is the mean of 30 plants where a sample of 30 plants could be obtained.

Since the dry weight of legumes is of primary interest, the data for dry weight of the above ground portions were analyzed by a "t" test to determine the significance of differences between treatment means, as suggested by Snedecor (41). Highly significant differences were found between all levels of light intensity. The greatest and the least dry weight yield occurred at 100% and 10% light intensity respectively. Alfalfa produced the highest yield and Ladino clover produced the lowest yield of the three legumes. Therefore, it could be assumed that alfalfa is the more shade tolerant and Ladino clover the least tolerant to light restriction.

Irrigation resulted in highly significant increases in

Table 22. Effect of four light intensities, 100, 50, 25 and 10% full greenhouse light, and irrigation on the vegetative growth and development of alfalfa, Ladino clover and birdsfoot trefoil at the end of 7 weeks. Values are the mean of 30 plants except as indicated

Light intensity (%)	100	100[a]	50	50	25[b]	25	10[c]	10[d]
Irrigation	+	-	+	-	+	-	+	-
Number of nodules								
Alfalfa	3.00	0.56	2.87	0.40	2.17	1.20	0.83	0.17
Ladino clover	2.33	0.71	5.13	0.18	2.63	2.67	0.38	0.00
Birdsfoot trefoil	0.53	0.40	0.80	0.03	0.50	0.27	0.00	0.00
Length of roots (cm.)								
Alfalfa	7.00	5.36	5.41	5.06	3.87	4.59	3.23	3.57
Ladino clover	2.90	4.66	4.43	3.59	2.83	2.71	1.55	1.88
Birdsfoot trefoil	4.38	4.05	4.72	3.62	2.45	2.76	1.72	2.67
Length of tops (cm.)								
Alfalfa	15.69	5.67	12.13	5.21	9.08	6.98	6.16	4.98
Ladino clover	6.09	4.91	12.67	2.45	6.93	6.02	3.72	3.05
Birdsfoot trefoil	11.36	7.51	11.23	6.70	6.98	6.45	4.82	6.35
Number of leaves								
Alfalfa	17.43	7.43	9.13	7.27	7.43	6.40	4.47	3.37
Ladino clover	3.17	3.36	4.30	1.89	2.63	3.53	1.62	1.50
Birdsfoot trefoil	19.50	21.37	12.63	11.63	7.25	6.87	4.53	4.82
Root weight (mgm. dry weight)								
Alfalfa	23.15	9.47	5.53	6.28	4.12	3.43	1.53	1.47
Ladino clover	3.45	4.18	3.59	1.69	1.30	1.34	1.01	0.70
Birdsfoot trefoil	7.06	6.91	3.45	2.75	1.64	1.88	1.34	0.41

[a]Fourteen Ladino clover plants.

[b]Twenty birdsfoot trefoil plants.

[c]Eight Ladino clover plants.

[d]Four Ladino clover plants and 11 birdsfoot trefoil plants.

Table 22. (Continued)

Light intensity (%)	100	100[a]	50	50	25[b]	25	10[c]	10[d]
Irrigation	+	-	+	-	+	-	+	-
	Weight of tops (mgm. dry weight)							
Alfalfa	114.12	36.30	43.08	27.82	28.93	22.13	10.31	7.71
Ladino clover	16.56	19.14	35.33	5.85	6.96	7.37	2.90	2.30
Birdsfoot trefoil	41.73	33.71	21.25	15.28	7.91	8.39	3.16	3.46

dry weight under all light intensities. However, when the effect of irrigation was tested at each light level, only at 50% light intensity was the effect of irrigation significant. Analysis of each legume showed the dry weight production of alfalfa to be significantly increased at 100%, 50% and 10% intensity by irrigation whereas yield of Ladino clover was increased at 50% intensity only and birdsfoot trefoil was not increased by irrigation at any level of light intensity.

Evaluation of the three legumes showed non-irrigated alfalfa to be unaffected in dry matter yield by light reduction while irrigated alfalfa was highly sensitive in that dry matter yield of irrigated alfalfa decreased as light intensity was decreased. Ladino clover yield, from the irrigated plants, was lower with each light reduction. Non-irrigated Ladino clover yields were decreased as intensity was reduced from 100 to 50% and from 25 to 10% intensities. Yields of non-irrigated Ladino clover at 50 and 25% light intensities were not significantly different. Birdsfoot trefoil yields were significantly reduced as light was reduced, irrespective of irrigation.

In general, legume yields were reduced by restricting light intensity. Irrigation for all light intensities and legumes increased yields but when the effect of irrigation was evaluated at each intensity, only at 50% light intensity did irrigation significantly increase yields. Therefore it can be assumed that irrigation cannot compensate for light restriction.

Root weight, length of tops and length of roots appeared to have been influenced in the same way by irrigation and light treatments. The deviations are less pronounced with irrigation than with light intensity but the changes are qualitatively similar.

Nodule number was greatly influenced by irrigation and was extremely sensitive to light reduction. This is in agreement with the findings of Pritchett and Nelson (35). Nodule formation apparently was the best on Ladino clover and the poorest on birdsfoot trefoil. Nodulation of birdsfoot trefoil was completely inhibited at 10% light intensity and as the intensity was increased, nodule number was only slightly increased. With alfalfa and Ladino clover, nodule number increased with increasing light intensity but showed the greatest increase due to irrigation at all light intensities.

DISCUSSION

The two years of field investigations on stand establishment provided opportunities to study the effects of weeds, companion crop and irrigation. The 1956 season was one of above normal temperatures and below normal precipitation while 1957 had near normal temperatures and slightly more than normal rainfall. Therefore, environmental conditions were such that when supplementary water was applied to the designated plots, four sets of conditions could be studied. With irrigation, in 1956, comparisons were made between hot and dry conditions and hot and slightly above normal moisture. In 1957, the comparisons were at near normal temperature with slightly above normal rainfall and normal temperatures with an abundance of moisture.

In general, where inter-species competition was present during establishment, stands of alfalfa were superior to Ladino clover and birdsfoot trefoil in the dry season. In the season of above normal rainfall, stands of alfalfa and Ladino clover were similar and superior to the stands of birdsfoot trefoil. This indicates a high degree of tolerance of alfalfa to hot dry conditions as compared to a low degree of tolerance of Ladino clover and birdsfoot trefoil to hot dry conditions during establishment. Under normal temperatures, Ladino clover exhibits a greater tolerance to inter-species competition than does birdsfoot trefoil and is equal to alfalfa.

Weeds, as an only source of competition, significantly reduced the stands, as measured by plant counts, of all three legumes in the season of above normal rainfall and reduced Ladino clover and birdsfoot trefoil stands during the dry season. The number of alfalfa plants per unit area was not reduced by weeds, as the only source of inter-species competition, during the dry season.

Consideration of the companion crop, as the only source of inter-species competition, indicated that stands of all three legumes were reduced during both seasons. During the dry season, the effect of the companion crop was greater than the effect of weeds on the alfalfa plots. The magnitude of the effect of the companion crop was equal to that of weeds with Ladino clover and birdsfoot trefoil during both seasons and with alfalfa in the season of above normal rainfall.

A generally accepted concept is that weeds and the companion crop exhibit strong competitive relationships when the legume is grown with each individually but when it is grown with both weeds and a companion crop, the effects of inter-species competition are additive. This study is not in agreement with that concept. In both seasons, alfalfa stands obtained when both weeds and a companion crop were present, were better than when the companion crop was the only source of competition but not as good as when weeds were the only source of inter-species competition. It may be hypothesized that with alfalfa, weeds exhibit a beneficial compensating effect on the companion crop as could result by reducing the available nitrogen and less growth of the companion and other competitors dependent on the soil nitrogen supply. With the other legumes, in both seasons, the effect of weeds and a companion crop was no greater than either weeds or the companion crop alone. Therefore the effects of weeds and the companion crop, growing together, were not additive. The explanation for this response rests in the fact that weeds are partially controlled by the companion crop.

In the absence of all inter-species competition, stands were better in 1957 than in 1956, although only birdsfoot trefoil showed a significant increase in plant numbers. Stands of alfalfa and Ladino clover were adequate during both seasons, while birdsfoot trefoil produced adequate stands only in the season of above normal rainfall.

In general, irrigation had no effect in increasing the stands of any of the legumes tested. With Ladino clover and birdsfoot trefoil in the year of above normal rainfall, irrigation resulted in a slight tendency toward more plants established, but the differences were not significant.

Since irrigation had no effect upon plant population and since fertility was maintained at a high level, it appears that in this study light was the growth factor which was most limiting in the inter-species competition. On fertile soil and with adequate rainfall, light probably limits stand establishment in most instances.

Plant population counts made the year after the 1957 seeding showed a carry-over effect of weeds and companion crop with alfalfa and birdsfoot trefoil. The same effect was present with Ladino clover as determined by estimation of the percent ground cover the year following seeding.

The capability of Ladino clover to produce stolons was evident in the ground cover obtained from so few plants established the year previously. Birdsfoot trefoil stands tended to be better in 1958 than in 1957 due to the inherent slow establishment of the crop. However, the improvement of the birdsfoot trefoil plots was so small that it was of little practical value.

With alfalfa under all treatments and Ladino clover and birdsfoot trefoil in the absence of all inter-species competition, during the year of establishment, plant populations decreased from 1957 to 1958. This reduction was due to winter-killing and to intra-species competition during the first harvest year.

Dry matter production of legumes for any given area is a manifestation of the number and size of the plants established. Inter-species competition between the legumes and companion crop or companion crop plus weeds markedly affected both size and number and resulted in very low dry matter production (hundredths of a ton) of alfalfa and essentially no dry matter production of Ladino clover and birdsfoot trefoil during the establishment years. Where weeds were the only source of inter-species competition, alfalfa produced a greater amount of dry matter during both seasons than either Ladino clover or birdsfoot trefoil. These yields also were of little practical importance.

Where all inter-species competition was omitted, alfalfa production with irrigation, during the dry season, was twice as large as birdsfoot trefoil and 5 times as large as Ladino clover. (Alfalfa produced 1.6 tons of dry matter per acre during the 1956 season). Without irrigation, alfalfa produced approximately 1 ton of dry matter per acre while Ladino clover and birdsfoot trefoil each produced 0.1 tons per acre. During the 1957 season, yields of alfalfa and Ladino clover, with or without irrigation, were approximately 1 ton per acre while birdsfoot trefoil produced 1.6 tons per acre with irrigation and 1.1 tons without irrigation. Thus it can be seen that alfalfa has the greatest tolerance to dry conditions while all three legumes exhibit a similar degree of tolerance to above normal moisture conditions.

Irrigation had no effect upon legume yields when inter-species competition was present. Therefore, since irrigation had no effect and since fertility was maintained at a high level, the growth factor limiting dry matter production appeared to be light.

Dry matter production in 1958 was conditioned by the number of plants present in the spring of the 1958 season and the growing conditions in 1958. Only during the month of July was rainfall above normal. Rainfall in May was deficient by 2.37 inches, August by 2.13 inches, June by 1.22 inches and April by 0.90 inches. Temperature during April and May was above normal while June and July were considerably below normal and August was slightly below normal.

Where a companion crop, weeds or both had been present in 1957, lower dry matter yields were obtained in 1958. In the absence of inter-species competition, dry matter yields were approximately 3.1, 1.4 and 3.9 tons per acre for alfalfa, Ladino clover and birdsfoot trefoil respectively. With weeds as a source of competition, dry matter yields were on the order of 1 ton per acre for alfalfa and birdsfoot trefoil and 0.5 tons per acre for Ladino clover. Where both weeds and companion crop had been grown the previous year, alfalfa yielded 1 ton per acre, Ladino clover 0.7 tons and birdsfoot trefoil yielded 0.3 tons per acre. Therefore it can be seen that the greatest competition during the seeding year produced the lowest yields the year following seeding. If dry matter production in the first harvest year is used to estimate the tolerance to competition during establishment, it can be seen that alfalfa is the most tolerant to all inter-species competition, Ladino clover is intermediate and birdsfoot trefoil is the least tolerant. This is in agreement with Blaser, et al. (8).

The 1958 yields showed a carry-over effect of the treatments imposed in 1957. Significant yield reductions due to weeds and the companion crop were observed. Irrigation the previous season had no effect upon dry matter production in 1958. Since 1958 yields were determined by the plant population and growing conditions in 1958, and since the growing conditions were the same for all plots, the 1958 yields became a function of plant population. The effect of inter-species competition has been previously discussed and it was noted that light had been the limiting factor during the establishment year. The effect of light restriction during establishment was not overcome during the first harvest season which shows the importance of light in obtaining good stands and subsequent yield.

Both Ladino clover and birdsfoot trefoil yields were greater in 1958 than could be forecasted from the 1957 yields. This was due to the stoloniferous habit of Ladino clover and the capability of birdsfoot trefoil to display tendencies toward becoming more prostrate and to branch extensively in the absence of all inter-species competition.

Weed yields were slightly higher in 1957 than in 1956. This was due to the above normal rainfall received in 1957.

The value of the companion crop as a weed control measure during the establishment of forages is well in evidence. Where the companion crop was grown during the dry season, weed yields were only 57% as large as where the companion crop was omitted. In 1957, the weed yields were reduced by 72% due to the influence of the companion crop. Therefore it can be seen that the weed control capability of the companion crop is greater during a season of above normal rainfall than during a dry season.

Irrigation significantly increased weed yields on the plots where the companion crop was grown in 1956 and 1957. In 1956, the dry season, irrigation on the plots containing a companion crop resulted in weed yields over 3 times as large as the non-irrigated plots. In 1957, the weed yield on the irrigated plots was 1.4 times the yield of the non-irrigated plots. On the plots which did not have a companion species, irrigation increased the weed yields by 1.7 times that of the non-irrigated plots in 1956 and had no effect in 1957.

Since irrigation increased the yield of weeds with a companion crop, the increase in the year of above normal rainfall was of lesser magnitude than in the dry year. This response is the normally accepted response to irrigation when a wet and dry year are compared. Without a companion crop, irrigation increased weed yield only during the dry year. The effect of the companion crop, on the other hand, was greater in the wet year than in the dry season. This can be explained on the basis that in a dry season the companion crop and weeds compete very favorably for moisture while in the wet season, the growth of the companion species is relatively larger than the growth of weeds.

Weed yields obtained in 1958 from legume seedings made in 1957 were relatively constant on all plots except those which had neither weeds nor companion crop present during the seeding year. In those instances weed yields were considerably lower than on the other plots. This was due to the fact that the weeds which germinated in 1957 were prevented from going to seed. On the other plots, some weed seed, particularly pigweed and foxtail, were scattered during harvest time. Therefore new seedings became established in 1957.

If the plots which had both the companion crop and weeds omitted in 1957 are excluded in the comparison in 1958, weed yields were significantly lower on the non-irrigated plots where weeds and a companion crop had been grown in comparison to where only the companion crop was grown. This difference, significant at the 5% level, probably was due to experimental error. In all other instances, there was no treatment carry-over effect on the weed yields obtained in 1958.

Neither weeds nor irrigation significantly influenced grain yields in either year although grain yields were slightly higher in 1957. However, on the plots containing weeds, irrigation reduced the grain yield. This was due to the growth response of weeds to irrigation and the subsequent shading effect of the weeds on the oat plant.

Irrigation increased the weight of the grain by 10% in the dry season but had no effect upon grain weight in the more favorable season. This is a typical response to additional moisture in dry years. Weeds on the non-irrigated plots had no influence upon weight of grain in 1956 but increased the weight per 1000 kernels in 1957. The same effect due to irrigation on the weed infested plots was obtained in 1956 but not in 1957. The effect of irrigation on the weed infested plots shows the competitive ability of the fast growing companion crop to successfully compete for supplementary water which ultimately went into heavier grain. The effect of weeds increasing the seed weight on the non-irrigated plots in 1957 probably was due to experimental error.

Neither weeds nor irrigation had a significant effect upon straw and chaff yield in either season. However, in the presence of weeds, irrigation resulted in lower straw and chaff yields than where irrigation was omitted during the dry season. This probably was due to the ability of weeds to compete favorably with the companion crop for the supplementary water and the subsequent shading of the oat plant by the weeds.

The greenhouse study with legumes seeded in moist soil confirmed results on the influence of light intensity on legume yields. As the light intensity decreased, legume yields, with the exception of Ladino clover at 50% light intensity, also decreased. This is in agreement with the field studies. Irrigation in the greenhouse stimulated legume production but only at one light intensity did it result in a significant increase in legume dry matter production. This occurred at 50% light intensity and was due entirely to the abnormally heavy growth of Ladino clover. At all other intensities, the effect of irrigation over all legumes, was not significant. This indicates that irrigation cannot compensate for the reduction in light intensity.

If each legume is considered separately, light intensity reductions had no effect upon non-irrigated alfalfa above the 25% intensity level. A significant reduction in growth was evident between 25 and 10% intensity. With irrigated alfalfa, the plants were sensitive to light reduction and each decrease in intensity resulted in a decrease in dry matter production. Ladino clover and birdsfoot trefoil were sensitive to light reduction irrespective of irrigation. Therefore it can be seen that alfalfa is more tolerant to shade than either Ladino clover or birdsfoot trefoil but irrigation of alfalfa results in a decrease in shade tolerance.

The effect of irrigation on each legume at each intensity showed a significant increase in dry weight production due to irrigation at 100, 50 and 10% light intensity for alfalfa, only at 50% intensity for Ladino clover but no significant influence on birdsfoot trefoil at any light intensity. This, like the field studies, is an indication of the aggressiveness of the legumes to utilize water whereas the slower growing Ladino clover and birdsfoot trefoil did not exhaust the water present in the soil at seeding.

The treatment effect on root weight, number of leaves and length of roots and above ground portions was similar to the treatment effect on dry weight production of the above ground plant structures. Although the magnitude of response was considerably more narrow with light intensity reduction and irrigation, the response was in the same direction. Therefore there is no reason to assume that the effect of the treatments, on the attributes other than dry weight of tops, is any different.

Nodule number, however, appeared to be affected by treatments. Nodule numbers were low because of the short time the plants were exposed to the treatments. Birdsfoot trefoil failed to develop any nodules at 10% light intensity and as the intensity increased, nodulation improved very little. With alfalfa and Ladino clover, nodulation was influenced by both light intensity and irrigation. Comparison of the non-irrigated areas shows nodulation was best at 25%, poorest at 10% and intermediate at 100 and 50% light intensity. Irrigation resulted in increased nodulation at all intensities with alfalfa and Ladino clover and comparison of the irrigated sections shows nodulation to be at its highest level at 100 and 50% intensities with alfalfa and at 50% intensity with Ladino clover.

Therefore it can be concluded that light intensity is a controlling factor in the growth and development of legume plants and that irrigation, in general, cannot compensate for light reduction in dry matter production and plant development. Irrigation improved nodulation under all treatments.

SUMMARY AND CONCLUSIONS

Studies were initiated in 1956 and 1957 on a Colo Silt Loam soil to determine the effects of the companion crop, weeds and irrigation and their possible interactions on the establishment of legumes. During the year of establishment, measurements were taken on the number of plants established, legume, weed and grain yield and weight per 1000 kernels of oats. Measurements of stand, legume and weed yield were taken in 1958, the first harvest season of the 1957 seeding.

The growing season of 1956 was hot and dry while the growing season of 1957 was one of normal temperatures and above normal moisture.

Greenhouse studies were initiated in 1958 to evaluate the effect of light intensity and irrigation on alfalfa, Ladino clover and birdsfoot trefoil seedling establishment and growth in the absence of inter-species competition. Measurements of dry weight production per plant, leaf number, root and shoot length and nodule number were taken.

The results of the study are summarized as follows:

1. The companion crop and weeds, grown alone or together, reduced the number of legume plants established and dry matter production of the legumes.

2. While the effects of the companion crop and weeds were deleterious to legume stands and dry matter production,

these effects were not additive when the companion crop and weeds were grown together.

3. The effect of competition from weeds and the companion crop during establishment reduced the number of alfalfa and birdsfoot trefoil plants present and the dry matter yields in the first harvest year, i.e. there was a carry-over effect. The stoloniferous habit of Ladino clover in the first harvest year tended to compensate for the deleterious effect of weeds and the companion crop during establishment.

4. The competition exerted by the companion crop reduced the weed yields during both seasons but had a greater effect during the season of above normal rainfall.

5. Irrigation had no effect upon the number of legume plants established or grain yields but increased weed growth which probably increased competition during the establishment of the legumes.

6. Since irrigation had no effect on the number of legume plants established and increased the competitive effect of weeds and the companion species as evidenced by reduced weed growth in the presence of a companion crop under irrigation and since fertility was maintained at a high level, the growth factor which was most limiting during establishment was light.

7. Without a companion crop or weeds, irrigation increased legume dry matter production in both seasons.

8. Irrigation increased weed growth and seed weight of oats during the dry season but had no effect during the season of above normal rainfall.

9. Irrigation of plots containing weeds decreased grain yields during both seasons and decreased straw and chaff yields only in the season of above normal rainfall.

10. The effect of irrigation during the year of legume establishment was not evident in the first harvest year as measured by the number of legume plants present at the end of the season, legume dry matter production or weed yield.

11. Weeds had no effect on oat grain yield, grain weight or straw and chaff yield during either season.

12. Weed yields obtained during the harvest year were not influenced by the presence of weeds, companion crop or both during the year of establishment. Where both weeds and the companion crop were omitted during the year of establishment, weed yields were significantly lower in the first harvest year.

13. Under greenhouse conditions, reduced light intensities resulted in reduced dry matter production of legumes.

14. Irrigation, under greenhouse conditions, did not compensate for reduced light intensities.

15. Growth and development of leaves and roots were adversely affected by reduced light intensities and the effects were not corrected by irrigation.

16. Nodulation of legumes was extremely sensitive to decreasing light intensity. However, non-irrigated alfalfa was not sensitive to light restriction as long as 25% or more of the incident greenhouse light was present. Irrigation increased nodulation at all light levels.

17. Alfalfa was more tolerant to the forces of competition and to reduced light intensity than was Ladino clover or birdsfoot trefoil. Ladino clover exhibited more tolerance to the same conditions than did birdsfoot trefoil.

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